DIAGRAMS OF NATURAL PHILOSOPHY.

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REYNOLDS, James
9/53

INTRODUCTION

TO

NATURAL PHILOSOPHY,

COMPRISING A POPULAR ACCOUNT OF

THE PROPERTIES OF BODIES;

MECHANICAL POWERS; MOTION AND MACHINERY.

THE SCIENCES OF

HYDROSTATICS; HYDRAULICS; PNEUMATICS; ACOUSTICS;

OPTICS; ELECTRICITY; MAGNETISM;

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NATURAL PHILOSOPHY.

The object of Natural Philosophy is to observe and describe the phenomena of the material universe with a view to ascertain their causes, and the subordinate laws by which the Almighty sustains and directs the movements of all things. It embraces an investigation of the laws of gravitation, by which the planets are directed in their motions; the laws by which water, air, light, and heat, are regulated, and the effects they produce in the various states in which they operate; the nature of colours, sounds, electricity, and magnetism, and the laws of their operation; the causes which operate in the production of thunder, lightning, luminous and fiery meteors, and other atmospherical phenomena. One subordinate use of the knowledge derived from this science is, to enable us to construct those mechanical engines which facilitate human labour and increase the comforts of mankind, and all those instruments which tend to enlarge our views of the operations of nature. A still higher and nobler use to which philosophy is subservient, is to demonstrate the wisdom and goodness of the Great First Cause of all things, and to enlarge our conceptions of the admirable contrivance and design which appear in the different departments of universal nature.

PROPERTIES OF BODIES.

No branch of Natural Philosophy can be understood without some previous knowledge of the general properties of matter; we shall therefore begin by taking a survey of these.

There are certain properties which appear to be common to all bodies, and are hence called the essential properties of bodies. These are Extension, Impenetrability, Divisibility, Porosity, Inertia, Cohesion, and Gravity.

Extension is the bulk of a body, its length, breadth, and thickness.

Impenetrability is that property by which two bodies cannot at the same time occupy one and the same place. If a nail be driven into a block of wood it will occupy the same space that the wood alone did before, it therefore displaces the particles, but does not become incorporated with them, (fig. 1). If in a full glass of water a stone be placed, the water will be forced over to make room for the stone, (fig. 2). Air is no less impenetrable than liquids, if we endeavour to fill a phial by plunging it into a basin of water, the air will rush out of the phial in bubbles in order to make way for the water, (fig. 3).

Divisibility denotes the property by which a body is susceptible of being subdivided into an indefinate number of parts. Animalculæ have been found so minute that a grain of sand would cover three hundred thousand of them, and each one has a perfect organization; fig. 4, represents the forms of some highly magnified. The fibres of a pound of silk will extend 583 miles. The diffusion of odours is another example of the divisibility of matter. If a bottle of lavender water be left open for a sufficient length of time, the whole will evaporate and disappear. But though so minutely subdivided as to be imperceptible to our senses, each particle would continue to exist; for it is not within the power of man to destroy a single particle of matter.

Porosity arises from the influence which heat exercises in separating the particles of matter, so as to produce vacant spaces or pores. A, fig. 6, is a piece of iron with a hole through it, and a notch in the side, B is a cylinder of iron fitting into the notch, and passing freely through the hole; upon heating the cylinder it will become so much expanded that it will neither fit into the notch nor pass through the hole, but when cooled again it will do both. If heat be applied to a vessel of water the particles of water are immediately put in motion, those near to the bottom of the vessel being heated first, and expanding, become specifically lighter and ascend; colder particles occupy their place and ascend in their turn, the heated particles rising up through the centre, and the colder ones descending at the sides, as shown by the arrows, (fig. 7).

Inertia, or as it is sometimes called Persistence, is the tendency of matter to preserve its present state, whether of rest or motion, unchanged. Fig. 8, is an illustration

of a body at rest inclining to remain so, if the card be struck away the coin remains balanced on the point of the finger. A body in motion has a tendency to proceed in a straight line; this is illustrated in the *doubling* of the hare when pursued by a dog. The dotted line (fig. 9) shows the course of the dog, which, at the points A B C, where the hare turns quickly, is irresistably thrown out of its track, and compelled to take a wider turn, thus affording the hare the only chance of escape.

Cohesion is the force by which the atoms of a body are held together in one solid mass. It is this power which holds a drop of water suspended at the end of the finger, and keeps its minute watery particles united, (fig. 10). This force is much stronger in some bodies than in others, the solidity or weight of the body corresponding to the cohesive attraction. *Capillary Attraction* is another effect of this power, which enables liquids to rise above their level in minute tubes, (fig. 11). Examples of this are very numerous, as the ascent of water in a lump of sugar, the pores of which act as tubes. Sap ascends in plants by the same force, and some idea of its intensity may be formed by fitting a dry plug of wood tightly into a stout glass tube, (fig. 12). If a projecting portion of the wood be allowed just to dip into water, the liquid will ascend and cause the wood to swell with such force as to burst the tube, although capable of resisting a pressure of 700lbs. on the square inch.

Gravitation is that force which causes all bodies on or near the earth to tend towards its centre, with a force proportioned to their respective quantities of matter, (fig. 13). All bodies attract each other inversely as the squares of the distances. All influences, emanating from a central point follow the same law. Fig. 14, illustrates the law in reference to light. The rays proceeding from the candle illuminate at a certain distance the space A B, at *twice* that distance they are spread over C D, four times the former space, and with four times less intensity; and in like manner, at *three* times the distance they illuminate the space E F, with nine times less intensity, and so on.

All bodies possess gravity or weight: there is no such thing as perfect lightness. Smoke ascends only because it is lighter than the atmosphere, (fig. 15); cork swims only because it is lighter than water. If the water be withdrawn the cork sinks; if the air be withdrawn, as it is possible by the air-pump, the smoke will sink like the cork.

The force of gravity is such at the surface of the earth, that in the first second of time, it gives to a body allowed to fall, a velocity of sixteen feet; in the next second forty-eight feet; and in the third second eighty feet. Knowing this law we can readily ascertain the height of a building, or the depth of a well, by noting the time a stone takes in falling. Fig. 16, shows the rate at which bodies fall; each of the triangular portions representing sixteen feet, the figures at the right side, the seconds. In consequence of the attraction of gravitation, all bodies falling to the ground would descend in the same time, were it not for the resistance of the air; owing to this resistance, however, the heavier the body, bulk for bulk, the more rapidly will it descend. Under the influence of the earth's attraction, a stone, when thrown upwards, takes precisely the same time to ascend that it does to descend; the velocity in the former instance being gradually diminished, and in the latter, accelerated by the force of gravity.

The Centre of Gravity.

The centre of gravity in a body, is that about which all its other parts equally balance each other. The method of finding the centre of gravity will depend entirely on the form of the body. If in a bar, (fig. 17) it is only necessary to balance it, and the centre of gravity will be at that point upon which it turns. The centre of gravity of a circular plate (fig. 18) is the centre of the circle; that of a sphere (fig. 19) its centre, C. The centre of gravity of a cone (fig. 20.) is at one fourth its altitude; that of a cylinder (fig. 21) at one half its altitude. The stability of a body resting on the ground depends greatly upon the centre of gravity. The body will stand, however tottering its position may be, provided the vertical line drawn from the centre of gravity fall within the base. The mass of rock, fig. 22, stands firmly, because a vertical line drawn from its centre of gravity falls within the base; while the mass of rock, fig. 23, will fall, as the vertical line falls beyond the base, showing that its centre of gravity is unsupported. The upsetting of a carriage depends very much upon the arrangement of the load, as regulating the centre of gravity; and, from want of attention to this, waggons and coaches laden heavily on the top will, upon coming on a road slightly inclined immediately upset. To prevent such accidents, vehicles should be built low and with wheels wide apart, (fig. 24). The danger of a boat being capsized will be much diminished if every one keep his seat, or what is still safer, lie down. Bodies having a narrow base are easily upset, for if they are the least inclined, their centre is no longer supported, as seen in fig. 25.

The centre of gravity in our bodies must constantly be adjusted, or we should be continually falling. When we walk up hill we lean forward, when we walk down we lean backward, when we stand on one foot we lean sideways; in each case, that the centre of gravity may not overhang the base. In rope dancing, (fig. 26) as the unstable base is only the breadth of the rope, the performer is provided with a long pole loaded at its ends, and when he finds his body inclining too much in one direction, he throws out his pole to the opposite point, and thus recovers his balance by bringing the centre of gravity vertically over the rope.

The Pendulum.

This body, which is represented at fig. 27, depends for its motion upon the forces of gravitation and inertia. When once set in motion it would continue to vibrate from side to side for ever, did not the resistance of the air, and the friction at the point of suspension, gradually overcome the influences by which the motion is sustained. The longer the pendulum the slower are its vibrations, and as the attraction of gravitation increases towards the poles, and decreases towards the equator, so the length of the pendulum requires to be regulated according to

the latitude, in order to preserve uniformity of speed in its vibrations. The length of the seconds pendulum in the latitude of London is thirty-nine inches, and about one-seventh of an inch, from the point of suspension to the centre of oscillation. The greatest possible nicety is required in the adjustment of the length, for a difference of only the 1,000th part of an inch, would cause a variation of a second a day.

As heat expands and lengthens pendulums, and cold contracts and shortens them, and as the smallest variation in their lengths makes a remarkable difference in time, various contrivances have been resorted to, to correct the expansion and contraction, and to preserve the centre of oscillation exactly in the same point; these are called *compensation* pendulums. Fig. 28, represents Graham's mercurial pendulum, consisting of a metallic rod and a cylindrical glass vessel, containing a certain quantity of mercury, which, expanded by the heat, rises as much within the vessel as the whole pendulum—rod and vessel —descends; or contracted by the cold, descends within the vessel as much as the pendulum is shortened; preserving in either case, the centre of oscillation in the same point. Fig. 29, represents Harrison's gridiron pendulum, made of alternate rods of brass and zinc, which are so placed, that the expansion of the one corrects the contraction of the other, and so keeps the centre of oscillation always in the same point.

Fig 30, is the balance wheel of a watch, with the balance spring, having one end attached to the axis at A, and the other fixed to the framing at B. The spring is lengthened by moving the index C towards the word *slow*, and shortened by moving it towards the word *fast*, producing a corresponding effect upon the movement of the watch.

Central Forces.

These are of two kinds, *Centripetal*, or the force of gravity, tending to the centre; and *Centrifugal*, flying from it. Centripetal force may be illustrated by a whirlpool at sea, or a whirlwind on land, (figs. 31 and 32). Centrifugal force may be illustrated in a variety of ways. If we whirl rapidly a sling with a stone in it, and suddenly allow the stone to fly off, it proceeds in a straight line, (fig. 33) till overcome by the force of gravitation and the resistance of the air, it falls to the ground. In turning rapidly a circular grindstone in contact with water, the water will fly off at right angles, (fig. 34). The process of grinding corn is a useful application of this force; the corn being admitted by an opening in the centre of the upper grinding stone, is quickly reduced to powder between the stones, and ejected at the edges in the form of meal. Another practical application of the centrifugal force is seen in the governor balls of the steam engine, (fig. 35), A A is a revolving shaft driven by the cog wheels B, and carrying two balls, which vibrate on levers, supported by the centre, C above; on the upper part of the shaft is a loose collar D, connected with the opposite ends of the levers by the arms E E, jointed at either end; when the balls are thrown apart by the increased rate of movement, they draw down the loose collar D, and with it the one end of the beam F attached to it, and consequently elevate the other end, which is connected with the throttle-valve of the steam pipe; and in this manner the supply of steam is accurately adjusted to the wants of the engine.

The centripetal and centrifugal forces are sublimely exemplified in the motions of the planetary bodies, the former, in their attraction towards the central luminary by gravitation; and the latter, in their tendency to proceed in a straight line by the force of inertia.

The velocity of revolving bodies increases in proportion to the distance from the centre of motion, The extremities of the vanes of a windmill move over a much greater space than the parts nearer the axis. The four dotted circles, fig. 36, describe the paths in which four different parts of the vanes of a windmill move; and though the circles are of very different dimensions, the vanes describe each of them in the same space of time. In like manner, as our globe turns on its axis, those parts nearer the poles describe smaller circles than those more remote; the equatorial regions describing the largest circle of all; and as all parts of the earth's surface describe each a circle in twenty-four hours, it follows, that the equatorial regions must move at a far greater velocity than the regions near the poles; and accordingly, the centrifugal force is greatest at the equator, and has caused matter so to accumulate there, that the earth's equatorial diameter is greater than its polar, by upwards of twenty-six miles; so that instead of a perfect sphere, the form is that of an oblate spheroid, (fig. 37).

Laws of Motion.

A body projected by a single force naturally proceeds in the direction of that force; but if in its progress a new force acts upon it, it will then be sent in a new direction; thus, a ball projected in the line A B C (fig. 38) strikes obliquely the ledge at C, there meeting an obstacle to its progress, which acts as a new force, causing it to rebound in the direction C D E, making the same angle with the ledge as did the original path of the ball, A B C. This is commonly expressed by saying that the angle of *incidence* is equal to the angle of reflection, the former meaning the angle A B C, and the latter C D E; and this is a law that applies equally to the motions of sound, heat, and light; and therefore, is of the utmost importance throughout physics.

The composition and resolution of forces, or motion, produced by two or more forces acting on a body in different directions at the same time, may be briefly considered. If two or more forces act upon a body at certain angles, a single force may be found which would produce the same effect. This single force is called the *resultant* or *equivalent*. For instance, a wind blowing from the north-west, and a current setting from the north-east, both acting on a ship, and tending to carry it with equal velocities in their own direction; the ship will be found to move in an intermediate direction, as if it were acted on by a single force, like a breeze, from due north. In fig. 39, we have an example of this; a ball receiving a blow in the direction A B, and at the same time a blow of equal force in the direction A D, does not pursue either of those directions, but takes a diagonal

course between them to C. The effect being the same as if the ball had been sent in the direction A C, by a single force.

The process of finding a single force equivalent to two or more forces is called the *composition of forces;* and the process of finding forces which will produce a motion equal to that of a single force, is called the *resolution of forces.* In fig. 40, this is illustrated in reference to the action of the wind upon the sail of a ship, and of the tide upon the helm. Let A B represent the direction of the wind acting upon the sail E F placed obliquely to it, then by drawing A C perpendicular to E F, and completing the parellellogram D B, the diagonal A B is resolvable into the adjacent sides A C and D B; now A C being at right angles to E F, will have the effect of propelling the vessel, although not in a straight line; but it may be guided in the desired direction by means of the helm, upon which the water reacts by the progressive motion of the vessel.

THE MECHANICAL POWERS.

Mechanics is that department of science which treats of motion and of moving powers.

The mechanical powers are essentially but two in number, but are usually considered as six; namely, the Lever, the Wheel and Axle, the Pulley, the Inclined Plane, the Wedge, and the Screw. The three first are assemblages of levers, and the three last inclined planes. One or more of these powers enters into the composition of every machine.

The Lever.

This is one of the most important and extensively used of all the mechanical powers. It consists of an inflexible rod or bar, resting on a support called a fulcrum, for the purpose of raising, by a power applied at one end, a weight at the other. The advantage gained is in proportion to the greater distance of the power from the fulcrum, than is the distance from the fulcrum to the weight to be raised; thus, if the distance from the power to the fulcrum be five times greater than the distance from the weight to the fulcrum, a force of one pound in the power will balance five in the weight.

There are three kinds of levers; the *first* kind is that where the fulcrum (F) is placed between the weight (W) and the power, (P, fig. 1). Levers of this kind are seen in a variety of instruments, as scissors, snuffers, pincers, &c., which consist of two levers acting contrary to each other; the fulcrum, or centre of motion, being the pivot on which they move. The common balance, (fig. 2) is a lever of the first kind, as is also the Roman steelyard, (fig. 3). In the case of the balance, the arms of the beam must be equidistant from the fulcrum; in the steelyard, the longest arm is that to which the power is to be applied. The article to be weighed being placed in the scale, a sliding weight is placed on the beam, and in proportion as the article in the scale is heavy, so is the weight slipped along to a greater distance from the fulcrum, and when it is brought to a point where it balances the article, the figure on the beam indicates the weight.

The boys amusement of see-saw, (fig. 4) is another illustration of a lever of the first kind, the bigger boy taking the shorter end of the plank, that his lighter companion at the longer end may balance him.

Fig 5, shows the application of a lever of the first kind in moving a heavy body; the nearer the fulcrum to the body to be moved the more powerful being the leverage.

In levers of the *second* kind, the weight is situated between the power and the fulcrum, (fig. 6). This kind of lever is seen in the common wheelbarrow, where the wheel is the fulcrum, the load in the barrow the weight, and the power the man who holds up the shafts. The oars of a boat present another instance; here the water is the fulcrum against which the blades of the oars press. A common use of this kind of lever is that of rolling or lifting forward a barrel or bale of goods.

Levers of the *third* kind are those where the fulcrum is at one end, the weight at the other, and the power between them, (fig. 7). Here the power acts with a considerable disadvantage, and this kind of lever is only used where the object is to produce great velocity, and which can only be effected by an expenditure of power. The footboard of a common turning lathe affords an example of this kind of lever. But one of the most striking instances of it is seen in the human arm in the act of raising a weight in the hand, when the lower part of the arm becomes a lever of the third kind, the elbow joint being the fulcrum, and the muscles which move the arm, the power, (fig. 8). The muscle by contracting its fibres less than an inch, raises the hand twenty inches; and if it raises also a weight of twenty-five pounds in the hand, it must act with a force at least twenty times as intense, or of five hundred pounds; thus showing the extraordinary strength of the living muscle.

Levers may be *combined* in a great variety of ways, and the aggregate effect of such combination is, as the product of the effect of the separate levers. Fig. 9, represents a combination of levers of the first kind, in which the power of the small weight P brings down A, which raises B, bringing down C, and consequently raising D; and thus, if properly supported, will balance the large weight W. By this means a weight of one pound will balance one of a hundred and twenty pounds.

The Wheel and Axle.

The wheel and axle may be considered as a kind of perpetual lever, of which the fulcrum is the centre of the axis, and the long and short arms the radius of the wheel and the radius of the axle, as shown at fig. 10; the power P acting upon the weight W, through the intervention of the lever A B, whose fulcrum is the centre of the axle. Supposing the semi-diameter of the wheel to be six times greater than the semi-diameter of the axle, a power of one will balance a weight of six, exactly upon the principle of a lever of the first kind.

There are many modifications of this mechanical power; one of the most common is the windlass for raising water from a well by means of buckets, (fig. 11). In this case the circumference described by the handle represents the wheel. The capstan used on board ships for drawing up the anchor, &c. is an upright axle, the moveable bars or levers, acting as the wheel, (fig. 12).

Wheels are very essential parts of most machines; they are employed in various ways; but when fixed to the axle their mechanical power is always the same; that is, as the circumference of the wheel exceeds that of the axle, so much will the energy of the power be increased. Like the lever, the wheel and axle may be used in combination, the circumference of one wheel acting by means of teeth upon the axle of another, as shown at fig. 13; the effect of such combination being similar to that produced by the combination of levers already described.

The compound axle (fig. 14) is a contrivance by which the power is increased, without increasing the diameter of the wheel. This axle has one half of it twice the diameter of the other half. A moveable pulley being attached to the weight to be raised, the rope is passed round the wheel, and coiled in the same direction upon both parts of the axle; upon every revolution of the axle, a portion of the rope equal to the circumference of the thicker part will be *drawn up*, but at the same time, a portion equal to the circumference of the thinner part will be *let down*: hence, every revolution of the cylinder raises the weight through a space equal to half the difference between the circumferences of the thicker and thinner parts of the axle. By this means a considerable mechanical advantage is gained; for supposing the weight to be forty pounds, there are twenty pounds upon either rope, and as the smaller axle contributes to the working of the larger, to the extent of one half, a power of ten pounds applied to the latter would balance the weight; but the diameter of the wheel, or of the circle described by the handle, being four times greater than that of the larger axle, a power of three pounds applied to the handle will be sufficient to raise the weight of forty pounds; but of course its elevation will be proportionally slow, in accordance with the well known law of mechanics, that an advantage in *power*, can only be purchased by an expenditure in *time*.

The Pulley.

The pulley is a small wheel turning on an axis, and having a groove upon its circumference for the reception of a rope. It is either fixed or moveable. The *fixed* pulley (fig. 15) possesses no mechanical advantage, but is used to change the direction of the power, or to give convenience in pulling. For instance, by pulling downwards, a weight may be raised upwards; or by pulling in one direction, a load may be made to proceed in another.

The *moveable* pulley, however, affords mechanical assistance by dividing the weight. This is illustrated at fig. 16, where the weight of the barrel is equally divided between the part of the rope affixed to the beam, and that held in the hand, which will consequently have only one half the weight to sustain. Fig. 17, shows this more clearly; if the large weight be twenty pounds, ten pounds is borne by A and ten pounds by P. The fixed pulley B, is of no other use than to change the direction of the power.

The power of pulleys is increased by their combination. Fig. 18, illustrates this, here the weight is equally distributed between four ropes, consequently it may be supported by a power only a fourth of its own weight. Fig. 19, is a system of pullies, or a *tackle* as it is usually called; by which a power of one hundred will balance a weight of six hundred. Fig. 20, exhibits a system of pullies in combination, in which a power of one will balance a weight of sixteen. The power of this system may be greatly augmented by substituting fixed pulleys for the hooks to which the ends of the ropes are attached, in the manner shown at fig. 21. In order to obviate the loss of power occasioned by the friction of the separate axles, where several pullies are employed, an ingenious arrangement has been resorted to in White's patent pulley, (fig. 22) by which all the pulleys in each block turn on the same axis, friction is thus reduced, and other advantages gained.

The Inclined Plane.

It is not difficult to understand, that a body may with much greater ease be drawn up a slope, than it can be raised the same height perpendicularly. Hence the advantage of the inclined plane, which acts as a mechanical power, in partly supporting the weight, (fig. 23). The longer the inclined space is in proportion to the perpendicular height, the greater is the advantage afforded. Suppose the inclined plane A B, (fig. 24) to bear the proportion to the perpendicular height B C, as three to one, then a power of one will balance a weight of three.

Persons have often been struck with astonishment when viewing Stonehenge, how those enormous cross pieces of stone were raised to the elevation at which we see them, but the mechanical feat is by no means very wonderful; for it would only be necessary to raise an inclined plane of earth in the direction of the line A B, (fig. 25) and by means of rollers placed under the stone, pass it to its situation on the top; the earth being removed, the stone would remain secure.

The Wedge,

The wedge is a combination of two inclined planes united at their base, (fig. 26). The mechanical advantage gained is in proportion as the length of the two sides is greater than the back. The wedge, however, derives its great power, chiefly from the way in which the force is applied—by being struck.

The wedge is a mechanical agent of singular efficacy; by its means the walls of houses may be propped, rocks split, ships raised, and a resistance overcome, to which it would be impossible to apply the lever, wheel and axle, or the pulley.

The Screw.

The screw is a machine of great mechanical power, and is a modification of the inclined plane, as will be seen by reference to fig. 27. A piece of paper being cut in the shape of an inclined plane, and wound round a cylinder, will show the threads of a screw. The screw has no power by itself, it can operate only by working in

spiral grooves corresponding to its threads; these grooves are formed on the inside of a box or nut, through which the screw winds itself, Fig. 28, shows the screw and its nut, Fig. 29, exhibits the screw with a section of the nut, showing the spiral grooves. The nut requires to be firmly fixed, in order that it may not turn with the screw. The power is applied by a lever, the screw, therefore, acts with the combined power of the lever and the inclined plane, thus becoming in reality a compound machine.

The advantage gained is in proportion as the circumference of the circle described by the lever, is greater than the distance between the spirals, or threads of the screw. Thus, supposing the threads to be a quarter of an inch apart, and the length of the lever twelve inches, the circumference described by the latter, will be seventy-two inches, or 288 times greater than the distance between the threads; consequently, a power of one pound acting against the end of the lever, will cause the screw to act with a force of 288 pounds.

Screws are much used in presses of all kinds. The bookbinders standing press (fig. 30) affords one of the best examples of this application of its power.

MOTION AND MACHINERY.

Machines act from the impression of a certain force, or power derived from human labour, that of horses, or from the force of wind, water, or steam; and in some cases from that of springs or weights. The motion is usually communicated to a machine in a rotary or circular form, and is, by certain contrivances, diffused through the whole organization, and changed into every conceivable direction. The various parts may also be made to move with any degree of velocity.

Figs. 1 and 2, represent the ordinary method of transmitting circular motion by means of endless bands passing over cylinders, or drums, the larger drums driving the smaller ones.

Fig. 3, shows the mode of converting, by means of an endless cord or band, the vertical movement of the axis A into the horizontal movements B C and D.

Where circular motion is required to be transmitted in a direction not parallel to the driver, bevel wheels (figs. 4, 5, 6) are generally used. These are made of various forms, suited to the angles at which they are required to act.

Fig. 7, represents the endless screw, each revolution of which causes the large wheel in which it works to move the space of one tooth. If the wheel therefore have sixty teeth on its circumference, the screw would have to make sixty revolutions for each revolution of the wheel. Circular motion may be converted into rectilinear by means of the wheel and rack, (fig. 8).

Fig. 9, represents the eccentric, the use of which is to convert circular motion into reciprocating, or alternate rectilinear motion. An eccentric wheel has its axis at a point nearer to one side than to the other, and being fixed to a revolving shaft, it consequently describes a path of gradually rising and falling in its revolutions. Upon the circumference of the wheel an iron hoop is placed, in such a manner that the wheel may slip freely round; the hoop is the extremity of a rod which communicates the motion produced. The eccentric is of great importance in the steam engine, in working the valves of the cylinder.

Fig. 10, represents the crank; this is one of the simplest and most useful methods of changing an alternate rising and falling motion into continued circular motion.

In most machines, both the moving force and the resistance to be overcome, are liable to fluctuations of intensity during the working. These are remedied by a reservoir of power, which is usually in the form of the fly-wheel. This wheel is generally formed of iron, the rim being made very heavy; in most cases it is placed in close connection with the original moving force, the effect of which it equalizes in its passage to the machine. The diagram, (fig. 11) represents the fly-wheel of a steam engine; it is turned by means of a crank fixed to the axle, and acted upon by the connecting-rod of the beam.

One of the most important changes of motion that can be effected by machinery is that of converting a reciprocating rectilinear motion, into a reciprocating circular one, or vice versa. The common bow used by watch-makers and other artizans, is an example of this, (fig. 12). The bow-string being rolled once round a small wheel carrying the piercer, an alternate rectilinear motion in the bow, produces an alternate circular motion in the wheel. The parallel motion of Watt is, however, the most beautiful example of mechanical contrivance for effecting this change. The piston of the steam engine being urged up and down in the cylinder in an exact straight line, and the end of the beam to which the piston-rod has to be attached, moving alternately in a circular arc, it became a difficult problem to connect these in such a manner, that a perfectly smooth motion, free from strain, should be imparted from the one to the other. The difficulty was overcome by the arrangement shown at fig. 13.

Fig. 14, represents the universal joint, a simple and effectual method of transferring rotation from one axis to another. The fusee of a watch affords an example of the beautiful adaptation of the wheel and axle to preserve regularity of action by a *variable* force. The watch derives its motion from the main-spring, (fig. 15) which is wound up by a spindle into a compact form, and the force communicated by the relaxing of the spring, varies in its intensity, being greatest when it begins to relax, and gradually becoming weaker, till its expansive energy is exhausted. To provide for this variation of force, the fusee is arranged into a series of circles (A B, (fig, 16) varying in their diameter; at first, when the force of the

spring is greatest, the chain acts upon the smallest circle; in other words, it pulls with a small lever, and in proportion as the intensity of the force weakens, and the barrel uncoils the chain from the fusee, and winds it about itself, so does the chain act upon a longer lever. Thus, the gradual diminution of force is counter-balanced by a gradual increase of lever advantage.

An increase of velocity may be obtained by passing an endless band round a large wheel, as A, fig. 17, and then round a small wheel, B. If the diameter of the large wheel be four times greater than the diameter of the small wheel, the latter will revolve four times for each revolution of the former. The wheel and pinion is another method of effecting this object. It is sometimes necessary that a machine, or part of a machine should be propelled with a velocity which is constantly changing from fast to slow, and from slow to fast. This is effected by the apparatus represented at fig. 18, consisting of two conically-shaped drums, having their larger diameters in contrary directions; they are connected by a belt, which is so governed by proper mechanism, that it is gradually shifted along from one extremity of the cones to the other, thus acting upon circles of different diameters, causing a continual change of velocity in the driven cone, with relation to that which drives it.

Fig. 19, represents a wheel and pinion. A is a wheel moving on its axis; B is a pinion one-fourth the diameter of the wheel. For each revolution of the wheel, the pinion will revolve four times. By a suitable combination of wheels and pinions a still greater difference in speed may be obtained.

Fig. 20, represents the wheels and pinions for moving the minute and hour hands of a dial. As the hour hand A is required to move twelve times slower than the minute hand B, there is fixed upon the axle of the centre wheel, the cannon pinion C, having ten teeth, in which work those of the wheel D, containing forty teeth; and, therefore, revolving four times slower than C. The minute wheel pinion E, containing twelve teeth, drives the hour wheel F, this wheel is fixed to a bush, revolving freely upon the axle of the centre wheel, and carrying the hour hand; and as the hour wheel has three times as many teeth as the minute wheel pinion, it revolves three times slower, and the minute wheel revolving four times slower than the cannon pinion; consequently, the hour wheel revolves twelve times slower than the centre axle. Thus, while the minute hand in the space of an hour traverses the whole dial, the hour hand traverses only one-twelfth part of it.

Fig. 21, represents a clock. The maintaining power is the weight A, acting by the cord upon the barrel B, to which is attached a large wheel giving motion to the pinion C, which carries the minute hand; while the pinion D gives motion to the hour hand. The division of minutes and hours being thus obtained; the next step is to regulate the motion of the train of wheels and pinions; this is effected by the escapement, consisting of the wheel E and balance F. The pallets G G, are intended alternately to take the teeth of the wheel in which they act; this produces the ticking sound so audible in every species of clock. The balance F continually oscillates to and fro, and by its slow regular motion, gives uniformity to the operation of the wheel work of the clock.

Fig. 22, represents the common clock escapement wheel and pallets, the pendulum being connected with the verge of the latter by means of a bent wire.

Fig. 23, represents the escapement of a lever watch, in which the impulse is given to the balance by a lever attached to anchor pallets.

Fig. 24, exhibits the principal parts of a corn mill. On the shaft of the water wheel, from which the motion is derived, is fixed a cog-wheel, A, which acts against the upright staves of the trundle B, driving it round, and with it the upper millstone, which is fixed to the top part of the spindle C, the spindle passing through a hole in the centre of the lower millstone. D E is a round box enclosing the millstones, with an aperture at the top, through which the corn from the hopper F, passes down between the stones; the supply being regulated by means of the shoe G, so adjusted by the line H, as to enlarge or diminish the opening at the bottom of the hopper. By means of a screw and nut I, the bridge tree K, which supports the lower end of the spindle C, may be elevated or depressed, producing a corresponding elevation or depression of the upper millstone, according as the corn is required to be ground coarse or fine.

Fig. 25, represents a machine for printing newspapers, &c. It prints both sides of the sheet during its passage through the machine, and is capable of throwing off one thousand sheets per hour. The mode of operation is as follows. The damped paper being piled upon a table, A, a boy standing on the adjoining platform takes up one sheet after another, and lays them upon the feeder B, which has several linen girths passing across its surface, and round a pulley at each end of the feeder, so that when the pulleys begin to revolve, the motion of the girths carries forward the sheet, and delivers it over the entering drum C, where it is embraced between two series of tapes that pass round a number of tension rollers. The paper is thus conducted under the first printing cylinder D, to the second cylinder E, and passing under which, it is then received completed by a boy. These two great cylinders are made of cast iron, turned perfectly true; they are covered in those parts corresponding to the typographic impression with fine woollen cloth. The drums F and G are made of wood; and serve to conduct the sheet evenly from one printing cylinder to the other. The various cylinders and drums revolve very truly by meant of a system of toothed wheels and pinions mounted at their ends. Two horizontal forms of type are laid at a certain distance apart, upon a long carriage H, adjoining to each of which there is a flat metallic plate, or inking table. The carriage bearing its two forms of type and two inking tables is moved backwards and forwards from one end of the machine to the other, and in its traverse brings the type into contact with the sheet of paper clasped by the tapes round the surfaces of the printing cylinders. This alternate movement of the carriage is produced by a pinion working alternately into the opposite sides of a rack under the

table; the pinion being driven by the bevel wheels I. Two similar sets of inking apparatus are provided; one at each end of the machine, adapted to ink its own form of type. The ductor roller K, has a slow rotatory motion communicated to it by a cord, which passes round a small pulley at the end of the printing cylinder. A horizontal metallic plate stands nearly in contact with the ductor roller. This plate has an upright ledge behind, forming a sort of trough, whence a small portion of ink is imparted to the roller as it revolves over the table. Another roller covered with a composition, called the vibrating roller, travels between the ductor roller and the inking table; the vibrating roller as it rises touches the ductor roller for an instant, abstracts a film of ink from it, and then descends to transfer it to the table; this being evenly inked is made to pass under three or four inking rollers, and impart to them an uniform film of ink, to be immediately transferred by them to the type. Motion is given to the whole system of machinery by an endless strap from a steam engine, passing round a pulley at the end of the axle at the back of the frame.

HYDROSTATICS.

This department of science treats of the pressure and equilibrium of liquids, the most remarkable property of which is, that of *equality of pressure.* This property arises from the extreme minuteness and independent gravitation of each of the particles, and from the manner in which they act upon each other; being arranged, not perpendicularly one above the other, but obliquely as shown at fig. 1. One particle above pressing between two particles beneath, the latter consequently sustain a lateral pressure, just as a wedge driven into a piece of wood separates the parts laterally. This lateral pressure is the result therefore of the pressure downwards, or the weight of the liquid above.

Fig. 2, illustrates the different degrees of force with which water flows from apertures in a vessel at different heights. As every particle acts independently of the rest, it is only the column of particles immediately above the orifice that can weigh upon and press out the liquid. The pressure of liquids upwards is likewise a consequence of the downward pressure. Fig. 3, represents part of a tea-pot, which we suppose to be filled with columns of particles of water; the particle 1, at the bottom, will be pressed laterally by the particle 2, and thus be forced into the spout, where meeting with the particle 3, it presses it upwards, and this pressure will be continued till the water in the spout has risen to a level with that in the pot.

Fig. 4, is another illustration of the upward pressure of water. A is a glass tube, widened at the lower end, against which, by a string passing up the tube, a thick piece of metal is held close by the hand. Upon immersing the glass and plate thus held together, in the water to a certain depth, the hand may be withdrawn from the string, the upward pressure of the water being sufficient to support the piece of metal.

Several interesting illustrations can be offered to prove the remarkable fact, that the pressure of water on the bottom of the containing vessel does not at all depend on the quantity of water, but upon the size of the base, and the perpendicular height at which the water stands.

Figs. 5 and 6, represent two vessels of precisely similar capacities, and each containing the same quantity and weight of water, but which have very different pressures upon their bottoms; that upon C D, being less than the absolute weight of the water, viz. the weight only of the cylindrical column A B C D; while that upon G H is more than the absolute weight of the water, viz. the weight of a cylindrical column E F G H, for the water in the central column G H I K, presses laterally with the same force, as it does on the part on which it stands; and thus an uniformity of pressure is exerted over every part of the bottom.

Fig. 7, illustrates the latter case still more strikingly; F is a tube communicating with the chamber E E, and on these being filled with water, the pressure upon the bottom, C D, will be precisely the same as if the whole space, A B C D, were filled with water.

Fig. 8, represents the hydrostatic bellows, which has been contrived to exemplify the great effect of a column of water. The tube A communicates with the interior of the bellows, and upon these being filled with water, the upper board B will be raised, and enabled to sustain a very considerable weight; for if the tube A hold but an ounce of water, and have an area equal to the thousandth part of the area of the top of the bellows, the ounce of water in the tube will sustain a thousand ounces placed on the bellows.

The pressure which may be produced by a small but high column of water is so enormous as to sufficiently account in the operations of nature, for the rending of a mountain; for should a small reservoir of water (as A A, fig. 9) of only a few yards superficial extent, be collected and closely pent up within the mountain, and a small crevice of no more than an inch in diameter, but two or three hundred feet in height, become filled with water, the pressure produced would amount to many thousand tons, and would in time probably rend the mountain asunder.

Another important principle in reference to liquids is their tendency to seek a uniform level. The free motion of the particles among each other, causes them to accommodate themselves to the shape of any vessel; the force of gravity also causes them to seek the lowest level for repose. The result of this general tendency is a perfect levelness of surface throughout the whole of any connected piece of water. If we pour water into a bent tube, as fig. 10, it will stand at an equal height in both limbs.

If there be two tubes or limbs of a tube connected

together, however different their width or form may be, a liquid poured into them will stand at the same level in both, and thus a portion, however small, will balance a portion, however large, as shown at fig. 11. The large mass A B being supported by the small quantity C D; the line A C being the level of both.

Fig. 12, represents a number of vessels of different forms fixed in the vessel A B so as to communicate with it, and by means of it with each other. Water being poured into any one of them will stand at the same level in all, as shown by the line C C.

From these considerations, a most important conclusion follows, namely, that water will, by being confined in pipes or close channels, rise to the height from whence it came, that is, as high as its source; and upon this principle depends all the useful contrivances for conveying water into towns and houses, by pipes from distant reservoirs. References to figs. 13 and 14, will illustrate this more clearly. A (fig. 13) is a reservoir of water, situated at a greater elevation than the town to be supplied; B is a pipe connected with the reservoir, and proceeding down into a valley, and thence upwards to the town, where it is subdivided into a great number of smaller pipes, which supply the different houses, to the upper parts of which the water will flow in its endeavour to seek the same level as the reservoir from whence it came.

Fig 15, represents the water level, the action of which depends on the principle that water in a communicating vessel will always preserve the same level; A B is a tube with the open ends turned up, and filled with water to a certain height, upon which is placed two floats C D, carrying upright frames or sights, each having a fine wire drawn across it, these are placed in a direction transverse to the line of the tube, and always preserve an horizontal position; if the eye be applied to one sight, and the other be brought to bear upon it, the horizontal direction of any object, or its degree of elevation is at once ascertained.

Fig. 16, represents the common spirit level, which consists of a cylindrical glass tube, filled with spirits of wine, except a small space, in which the air is left. The tube being closed, the air bubble, from its lightness, will occupy the highest part of it, however slight the difference may be. When the surface to which the level is applied is perfectly horizontal, the bubble of air will be balanced in the centre of the tube, as seen at A.

Intermitting Springs.

Those springs, sometimes found upon hills, which flow and stop by regular alternations, may be accounted for upon the principle of the syphon, represented at fig. 17. If this tube be filled with water or other liquid, and the shorter leg be plunged into a vessel of water, the water will flow up the tube, over the bend, and out at the longer leg, till the vessel is emptied,

Fig. 18, represents a section of a hill, having within a cavity, A, from which runs a channel in the form of a syphon, in the direction B C. The rain falling upon the top and sides of the hill, percolates through the crevices and pores, *d d d*, and in course of time will fill the cavity with water up to the level, E E; it will then flow over the bend B, and continue to flow and supply the spring till the level of the water falls below the mouth of the channel, when the action of the syphon will cease, until by fresh supplies the level of the water is again raised, so as to flow over the bend, when the syphon will act as before.

The Hydrostatic Press.

Fig. 19. This is perhaps the most powerful machine ever invented, the only assignable limits to its power being the strength of the materials of which it is formed. A is the force pump, by the action of which, water is forced through the small tube B B, and its pressure communicated to the mass of water in the cylinder C, there the water, in its endeavour to resist compression, forces up the moveable piston D D, with its burden; and the action of the pump being continued, the pressure is gradually increased, until the required degree is produced, when a screw stop cock being turned upon the water, the machine remains at rest.

To show the vast power of this machine, it may suffice to state that, supposing the diameter of the piston to be ten inches, and the tube half an inch, a pressure of sixty pounds applied to the end of the pump handle, would cause a pressure upon the piston of 168,000 pounds.

Fluid Support—Specific Gravity.

A solid body immersed in a fluid displaces exactly its own bulk of fluid, and the force with which the body is buoyed up, is equal to the weight of the fluid which is displaced; therefore, the body will sink or swim, according as its own weight is greater or less than the bulk of the displaced fluid. This refers to bodies of less density than water. Any body of greater density than water, when wholly immersed in that fluid, loses exactly as much of its weight as the weight of an equal bulk of the water which it displaces.

These laws are of much importance, as an acquaintance with them enables us to explain innumerable phenomena in nature, in reference to the floating of bodies in water, or in the atmosphere.

Fig. 20, is a vessel of water, and A, a solid body of the same density, immersed in it, and which, being equally pressed upon from above and below, retains its position, just as the mass of water it has displaced would have done. But if a solid body as B, fig. 21, heavier than water, bulk for bulk, be placed in it, it will sink to the bottom; while a body lighter than water will float on the surface partially immersed, as A, fig. 21, the weight of the water displaced being equal to the weight of the whole solid. Thus, the weight of any floating body may be ascertained by measuring the quantity of water which it displaces.

Fig. 22, represents the hydrostatic balance, used for ascertaining the specific gravity of solid bodies, which are suspended in water, by a horse-hair attached to the bottom of one of the scales. This balance is much used by goldsmiths to detect alloys in the precious metals.

Hydrometers.

These are instruments, which being immersed in liquids, determine the proportion of their densities, or specific gravities, and thence their qualities. The use of the hydrometer depends on the following propositions. 1.

The hydrometer will sink in different fluids in an inverse proportion to the density of the fluids. 2. The weight required to sink an hydrometer equally far in different fluids will be directly as the fluids. Each of these two propositions give rise to a particular kind of hydrometer; the first with the graduated scale, as fig. 23; the second with weights, usually hollow glass beads of various weights, which are dropped into the liquid till one is found to remain stationary, indicating the density of the liquid.

Fig. 24, represents Nicholson's hydrometer, consisting of a hollow copper ball A, with a steel stem B, supporting a small dish C; attached to the lower part of the ball is another small dish, serving to keep the instrument in an upright position. By the successive addition of weights to the dish C, the instrument may be sunk so as to obtain the complete range of specific gravity, from that of pure alcohol to that of distilled water. An hydrometer of this kind is used for collecting the excise duty on spirits.

Fig. 25, represents the areometer, an instrument for determining the relative specific gravities of any two fluids which may be poured together without mixing, as mercury and water, oil and water, &c. The fluids are poured into the separate branches A B, till they meet exactly at the bottom, when their relative specific gravities are indicated by the scale in the centre.

HYDRAULICS.

This science, which may be considered a branch of hydrostatics, treats of liquids in motion.

The particles of liquids flow over or amongst each other with less friction than over solid substances, and all the particles gravitate independently. If a hole be made in the bottom of a vessel, the liquid will flow out, those particles directly over the orifice being discharged first, their motion causes a temporary vacuum, into which the particles tend to flow from all directions; and thus, the whole mass of the water is set in motion, (fig. 1). As water flows through bended pipes to the same level from whence it proceeds, it enables us to form jets or fountains, (fig. 2). If, for example, a body of water be collected in a reservoir on the upper part of a house, and a tube descending from it to the garden, be made to turn upwards, having a very small bore, the water will spout up in a jet to nearly the same height as the surface of the water in the reservoir. It will not rise quite so high on account of the resistance of the air, and the effect of gravitation. Most of the ornamental fountains in public gardens are formed upon this principle.

PUMPS AND MACHINES FOR RAISING WATER.

These may be divided into four classes. First, those machines in which water is lifted in vessels by the application of some mechanical force to them. The earlier hydraulic machines were constructed on this principle; such as the Persian wheel, (fig. 3), consisting of upright buckets attached to the rim of a wheel moving in a reservoir of water; the buckets are filled at bottom as they pass through the water, and emptied at top; the water is thus raised to a height equal to the diameter of the wheel. The Archimedian screw, (fig. 4), and the chain pump, (fig. 5), are modifications of the same principle.

The second class of machines are those in which the water is raised by the pressure of the atmosphere; and comprises all those machines to which the name of pump is more particularly applied. These act entirely by removing the pressure of the atmosphere from the surface of the water, which may thus be raised to any height not exceeding thirty-two feet.

Fig. 6, represents the common pump, which consists of a cylinder, with an air-tight piston, having a valve A, opening upwards. When the piston is raised, a vacuum is formed in the tube beneath, which is immediately occupied by the water; on depressing the piston, the water passes through the valve A, in its centre, and on its being raised, the water is lifted to the top of the barrel, and flows through the spout. To prevent the water returning to the well when the piston is depressed, a valve (B) opening upwards is placed near the bottom of the pump.

When it becomes necessary to raise water to a greater height than thirty-two feet, the third class of machines, or those which act by compression on the water, usually by the intervention of compressed air, are employed. All pumps of this description are called *forcing pumps*; and by these, water may be raised to any height, by applying sufficient force.

Fig. 7, represents the forcing pump, consisting of two parts or barrels, one similar to the common pump, and the other rising by its side. The water is first raised in the former part in the same manner as in the common pump, excepting that the piston has no opening valve, but is solid, and the air is forced out through the valve A, into the adjoining barrel. Through this valve the water is also forced, and the pressure of the descending piston causes it to flow up the ascending pipe, and issue out at the top. The vessel in which the lower end of the ascending pipe is placed, encloses a volume of air; when the water rises, this air is compressed, and being elastic, it reacts upon the water, thus causing it to flow upwards with greater force.

The fire engine is an interesting example of the utility of this machine; its principle will be readily understood by reference to fig. 8. A is the suction pipe by which water is supplied from the street main; B B are two valves opening upwards into the barrels of two forcing pumps, containing solid pistons; from the lower sides of the pump barrels proceed force pipes, which communicate with an air chamber, C C, by valves D D, opening upwards into it. Through the top of the air chamber descends nearly to its bottom a pipe, E E, to the upper part of which is attached the hose for directing a stream of water on the fire. By the alternate action of the pistons, water

is drawn through the valves B B, and propelled through the forcing valves D D; and the enclosed air being compressed, reacts upon the water, which is projected up the centre pipe and along the hose, with a force proportioned to the power applied to the pistons, by the persons who work the engine.

The fourth class of hydraulic machines for raising water, consists of such engines as act either by the weight of a portion of the water which they have to raise, or of other water, or by its centrifugal force, momentum, or other natural powers. The centrifugal pump (fig. 9) belongs to this class. This machine raises water by means of the centrifugal force, combined with the pressure of the atmosphere; A B is an upright spindle, so fixed that rapid rotary motion may be communicated to it by a wheel and pinion, or winch. C D, C D, represent any number of curved pipes, so disposed and fixed to the spindle that their lower ends may be near to it, and be covered by the water to be raised; and their upper ends to be extended to a considerable distance from the centre of motion, and bent downwards to prevent the scattering of the water. Before putting the machine in action, the several pipes must be filled with water, which will be retained in them by a valve near the bottom, opening upwards. The machine is then put in motion by turning the spindle rapidly. The upper ends of the pipes will describe a much larger circle than the ends below; and consequently, such a centrifugal force will be generated at the upper ends, as will produce a vacuum, and the water below will then rise and flow from the upper ends of the pipes into the circular trough, whence it may be delivered by a pipe as required.

Power to be Derived from Water.

Motion is generally obtained from water, either by exposing obstacles to the action of its current, as in water wheels; or by arresting its progress in moveable buckets, or receptacles which retain it during its descent. A water wheel consists of a hollow cylinder or drum, revolving on a central axle, from which the power is communicated; while the exterior surface is occupied by float boards, or cavities upon which the water is to act. Water wheels are divided into three classes; first, the *undershot* wheel, (fig. 10) having floats dipping into the water, the current of which, acting against them, causes the wheel to revolve. The second class are those termed *overshot* wheels, (fig. 11) in which the circumference is occupied by a series of cavities into which the water falls from above; as the wheel revolves, these cavities become inverted, and discharge their contents at the bottom of the wheel. This description of wheel is much more powerful, as well as much more economical in its consumption of water, than the preceding. The third kind of water wheel is that termed the *breast wheel.* In this, the water is delivered about half-way up it, or rather below the level of the axis, and the brickwork upon which the water descends is built in a circular form, so as to make it parallel to the edges of the float boards of the wheel, its arrangement and mode of action will be readily understood by reference to fig. 12.

Fig. 13, represents Barker's mill, a machine which owes its efficacy to the centrifugal force. It consists of a long cylindrical pipe, having a funnel at A, and terminating in a pivot, turning in a socket at B. About A is an axis, C passing through a frame, and carrying with it the upper millstone. At the bottom of the pipe at B is a cross pipe D E, at the opposite sides of which are two apertures from which the water poured into the funnel at A, spouts with considerable velocity, and from the resistance of the air gives motion to the machine.

PNEUMATICS.

This branch of philosophy treats of the nature and properties of the atmosphere, and of their effects upon solid and fluid bodies.

The atmosphere, or air, is a thin gaseous substance which rests upon, and envelopes the earth on every side to the height of about forty-five miles. It is most dense at the surface of the earth, and its density diminishes with its height. This will be seen by referenee to fig. 1; where the whole atmosphere is divided by lines into thirty parts, and though the spaces vary so greatly, yet each part contains an equal quantity of air; the lower layers being so much compressed by the weight of those above them, that the lower half of the atmosphere lies within about three miles and a half of the earth's surface, while the upper half is so expanded, as to occupy upwards of forty miles. The upper thirtieth part alone occupies more space than all the remaining twenty-nine parts.

Mechanical Properties of Air.

The most essential point in which air differs from other fluids, is by its spring or elasticity; that is, its power of increasing or diminishing its bulk, according as it is less or more compressed.

Air possesses the universal properties of matter. Its impenetrability may be proved in many ways, the following experiment will be quite convincing. Fig. 2, is a vessel partly filled with water, upon the surface of which floats a small cork. Fig. 3, is a smaller cylindrical glass vessel, furnished with a stop cock A, which is closed. Let this vessel be inverted over the cork, as at fig. 4, and its mouth pressed into the water to any convenient depth, and it will be found that the water will not enter the inverted glass, except to a very limited height, as will be seen by the cork floating on the surface. Thus, the air in the glass excludes the water. That this is the cause of the exclusion will be rendered apparent by opening the stop cock A, by which the air, that hitherto prevented the ascent of the water beyond the level C, will escape, and the water will immediately rise, until it stands at the same level within, as it does without the glass.

That air is inert and moveable we have many and

familiar proofs. Wind is nothing but air in motion; any obstacle that opposes this motion, sustains a considerable pressure, and must exert a proportionate resistance, otherwise, it will be carried forward with the body of moving air. If the air be quiesent, and there be no wind, there is a resistance opposed by it to the passage of any body through it. This resistance is produced by the force exerted by the body so passing through it, in displacing the air in its progress. If a large fan or open umbrella be moved slowly against the calm air, the resistance will be instantly felt. The air also possesses weight, one hundred cubic inches weighing about thirty-one grains.

Laws of Air.

First, the pressure of the air is equal in all directions; second, its degree of pressure depends on the vertical height or depth, and is in proportion to its density; thirdly, it affords support according to its density, and to the weight of the fluid displaced.

That air presses in all directions may be proved by filling a bladder with that fluid, and then pressing upon it; the pressure will be freely communicated through the mass, and the confined air will rush out with equal force, at whatever part a hole is made in the surface.

The pressure depending on vertical height or depth of air, is an important property of the atmosphere, and on it depends the explanation of numerous phenomena.

Air, being a substance possessing gravity, it necessarily presses downwards in the direction of the centre of the earth; and therefore, the degree of pressure on any given point, will be equal to the weight of the column of air above that point, and proportional to the density of the air at that point. The atmosphere is of the greatest vertical height at the level of the sea, and here its pressure is about fifteen lbs. on every square inch of surface. The pressure being exerted upwards, sideways, obliquely, and in every other direction, as well as downwards.

Many illustrations may be given of the pressure of the air. Figs. 5 and 6, represent two hollow hemispheres of brass, having smooth edges, which are placed in contact, and one of the hemispheres being provided with a short tube and stop cock, is screwed to an exhausting syringe, by which the air is withdrawn from the hollow sphere, the stop cock being then closed to prevent the admission of air, the apparatus is detached from the syringe, and a handle screwed to the tube. If two persons now pull in opposite directions, they will be unable to separate the hemispheres, which are pressed together by the force of the atmosphere of fifteen pounds upon every square inch.

It is the pressure of the atmosphere which causes liquids to rise in pumps, upon a vacuum being formed by the ascent of the piston, (*see Hydraulics*). The syphon also, acts by the pressure of the atmosphere being removed from the surface of a liquid, which enables it to rise above its common level, (*see Hydrostatics*).

The common leather sucker, with which boys raise stones, acts from the pressure of the atmosphere. The leather being made pliable by water, is pressed carefully down upon the stone. This pressing of the leather excludes the air from between the leather and the stone; and by pulling the string fastened to the middle of the leather, a vacuum is left underneath its centre; consequently, the weight of the air about the edges of the leather, not being counterbalanced by any air between it and the stone, enables the boy to lift it, (fig. 7).

The Barometer.

This instrument consists of a column of mercury, supported in a tube by the pressure of the atmosphere, and therefore, indicates most exactly that degree of pressure. It is formed by a glass tube, (fig. 8) about one-fifth of an inch diameter in the bore, and about thirty-four inches long, closed at one end, and open at the other. The tube being filled with quicksilver, the open end is stopped with the finger to prevent any running out, and the tube being inverted, the open end is placed in a small cup of quicksilver, and the finger being withdrawn, the mercury in the tube now subsides three or four inches, above the top of which, in the tube, is a perfect vacuum. The tube being then fixed to a graduated frame, we have a barometer. The mercury will now stand in the glass tube at the height of from twenty-eight to thirty inches, according to the state of the air; and the reason of this is, that the pressure of the whole atmosphere will not raise a column of mercury higher than about thirty inches; that is, a column of air equal to the height of the atmosphere, from the level of the sea, is of the same weight as a column of mercury thirty inches high, the one thus balancing the other.

The wheel barometer is represented at fig. 9. It consists of a narrow glass tube, upwards of thirty inches in length, closed at the top, and bent upwards at its lower extremity, which is open; the mercury is introduced with great care, so that a perfect vacuum exists at the upper end. The surface of the mercury at the bent part is open to the action of the atmosphere, and buoys up a small float F, to which a thread is attached passing over a small pulley, and terminating in the little ball W. The friction of the thread on the pulley turns an index I, which points to the words on the dial plate. The whole apparatus, except the dial plate, is usually concealed in an ornamental case.

The barometer usually ranges from twenty-nine to thirty inches; when it falls, an indication is given of diminished pressure; and as this causes the air to expand and become sensibly cooled, moisture is liable to be precipitated in the form of rain. Hence, a fall in the mercury of the barometer, is considered a prognostic of rain or wet weather, and a rise, the reverse.

The barometer is also used for the purpose of measuring the heights of mountains and other elevations, which it does upon this principle; as the entire atmosphere sustains thirty inches of mercury in the tube, it follows, that at every step as we ascend, the pressure will become less, and a shorter column will be sustained. It is found that at the height of five hundred feet, the mercury has sunk half an inch. But the fall does not proceed at this ratio as we proceed upwards, because one half of the entire atmosphere is so condensed as to lie within about three and a half miles of the earth's surface, and the other half is expanded over a space of upwards of forty

miles. Hence, on gaining an altitude of rather more than three miles, the mercury is found to have sunk to fifteen inches, or one half; and on gaining an height of four miles, to twelve inches, (see fig. 1).

The Air-Pump.

Air may be artificially withdrawn from a containing vessel by means of an apparatus called the air-pump, which consists chiefly of a glass cover, called a receiver, placed over the pump plate, which is connected by a tube with two small brass pumps, by which the air is withdrawn from beneath the receiver. Air-pumps are made in various forms; the one in most general use is represented at fig. 10, A is the receiver, having its edge ground perfectly smooth and true, so as to rest in close contact with the pump plate B, near the centre of which is the open end of a tube C C, communicating with the two exhausting barrels D D; these are fitted with pistons having valves opening upwards, so as to allow the air beneath to pass out, but preventing the outward air from passing into the machine. At the bottom of the barrels are two other valves also opening upwards, admitting the air from the tube into the barrels when the pistons are raised, and on their descent preventing its return; the air thus confined in the barrel, by the descent of the piston, becomes compressed, and forcing open the valve in the piston, escapes into the open air. Fig 11, is a section of the pump barrels D D, showing the mode of action. The pistons which work in the two barrels are connected by a rack and pinion movement with a handle, in such a way that when the handle is worked in semi-circular movements, the pistons are raised alternately, and a perfect vacuum is produced beneath the receiver.

By means of the air pump many interesting experiments in pneumatics may be performed. When the air is thoroughly exhausted, light and heavy bodies fall with equal swiftness; most animals die immediately, but frogs and adders continue alive a long time; vegetation stops; combustion ceases; gunpowder will not explode; heat is slightly transmitted; a bell sounds faintly; magnets are powerless; glow-worms give no light; and watery and other fluids turn to vapour. We thus see the important uses of the air in supporting life, vegetation and combustion; in forming a medium for conveying to us the sound of each others voices, and all the melodious notes which constitute music; besides contributing in numberless ways to our comfort and enjoyment.

Air Condenser.

Fig. 12, represents a section of the condensing syringe, consisting of a cylinder having an opening at A to admit the air, and a valve at B, opening downwards. To it is fitted a piston which forces the air through the valve B, the form of the valve preventing its return. The lower end of the instrument is provided with a screw to fit into the vessel into which the air is to be forced. Fig. 13, represents a vessel partly filled with water. By means of the condensing syringe, a large quantity of air may be forced through the tube into the space A A; if the stop cock be then closed, the syringe detached, and the stop cock reopened, the pressure of the air upon the surface of the water, will force it up in the form of a jet d' eau, to a height proportionate to the amount of condensation.

The elastic force of compressed air is very great, and is employed for the projection of balls from the air gun, (represented at fig. 14). A certain quantity of air being compressed into the round copper ball A, by touching a valve, a portion of it is allowed to escape into the barrel, and the ball is projected with a force resembling that of gunpowder.

Air Balloons.

The air balloon is a light silken bag of large dimensions, filled with a gas, which bulk for bulk is lighter than air, so that when inflated, the machine becomes considerably lighter than the air which it displaces, and this difference is so considerable that it is enabled to carry up with it several persons in a car attached. As it ascends, the air becoming less dense, the difference between its weight and that of the air displaced is gradually diminished, until it attains such a height, that the air it displaces, is so rare, as to be only equal in weight to the balloon; this, therefore, becomes the limit of its ascent. In order to descend, the bulk of the balloon is diminished, by the gas being allowed to escape by opening a valve; thus, the weight of the ballon is made to exceed that of an equal bulk of air, and it accordingly falls.

The Diving Bell.

Fig. 16. This machine is formed of iron, and usually capacious enough to hold three or four persons. It is constructed on the principle of the impenetrability of air, before described. Air is pumped in from above by means of a forcing air pump, or condenser; the water is thereby prevented from rising in the machine, and the persons within are enabled to breathe freely. A represents the pipe conveying the fresh air from the force pumps, and B the pipe conveying the vitiated air from the bell.

ACOUSTICS.

Acoustics is the science of sound and hearing. If a bell (fig. 1) be struck by its clapper, the body of the bell vibrates, and in its agitation, beats or makes impulses on the air, which, yielding under the stroke, is compressed or condensed to a certain distance around. The compressed air instantly expands, and in doing so repeats the pressure on the air next in contact with it; and thus each of the original strokes of the vibrating metal, sends out a series of shells of compressed air, somewhat like the waves dispersed over a lake from the dropping of a stone into its calm surface. The air thus agitated, finally reaches the ear, where it gives a similar impulse to a very fine membrane, and the mind then receives the idea of sound.

Sound travels at the rate of 1,125 feet per second,

advancing with undiminished velocity, but with unequal intensity. It thus travels a mile in little more than four seconds and a half, or thirteen miles in a minute; the softest whisper and the loudest thunder travelling with equal velocity. The intensity of sound increases or diminishes with the increase or decrease of the elasticity of the air. Hence, in proportion as the air is rarified, sound loses its force.

An echo, or duplication of sound, is one of the most interesting phenomena in acoustics. The cause of it is precisely analogous to the reaction of a wave of water striking the precipitous bank of a river, it is thrown back in a diagonal direction to the side whence it came, and there again strikes on the bank. In the same manner, the pulses or waves of sound are reflected or thrown back from flat surfaces which interrupt them, and, thus returning, produce what we call an echo. An echo may be double, triple, or quadruple, according to the nature and number of the projecting surfaces from and to which the sound is allowed to play. One of the most interesting echoes of this kind in nature, is that which occurs on the banks of the Rhine at Lurley. The report of a pistol fired on one side, is repeated from crag to crag on the opposite sides of the river, as represented at fig. 2. P being the primary point of radiation for the sound, which crossing the river, strikes at A, whence it is reflected to B, and so on to C D, and E, where it faintly dies away.

The concentration of sound by concave surfaces, produces many curious effects. The whispering gallery of St. Paul's, London, affords an example in illustration. Fig. 3, represents the circular dome, S the speaker, and H the hearer. Now as sound radiates in all directions, a part of it will proceed in a straight line from S to H, while the other rays of it will proceed from S to A A, S to B B, &c.; but the ray that infringes upon B B, will be reflected to H, and that which strikes at A A, will be reflected to B B, and from thence to C C, and on to H; and so of all intermediate rays. Consequently, the sound at H will be much stronger than if it had proceeded immediately from S, without the assistance of the dome. The mere shutting of the door at S, produces a sound like a peal of thunder rolling among mountains.

Fig. 4, represents a speaking trumpet. These instruments are constructed on the principle of the reflection of sound. The voice, instead of being diffused in the open air, is confined within the trumpet; and the vibrations which spread and fall against the sides of the instrument are reflected according to the angle of incidence, and the rays (distinguished by the dotted lines) are brought to a focus at F, at which point the sound is prodigiously increased.

Fig. 5, represents the hearing trumpet, which acts upon the same principle; the rays of sound in this case being collected into a focus, near the small end of the instrument, which is applied to the ear. Acoustic tubes, represented at fig. 6, are used for conveying messages from one apartment to another at a distance. The mouth of the speaker being applied at one end of the tube A, the message is received by the person at the other end applying his ear to the orifice B.

The Ear.

The mechanism of hearing is beautifully adapted to the purposes of life. From the external part of the ear, (fig. 7) proceeds a tube leading into the head, and the sounds collected and concentrated at the bottom of this tube, fall upon a fine skin or membrane, A, called the membranum tympani, which is extended over the circular opening of the bottom of the tube. Behind this membrane is a curious chain of four small bones, B C D E, forming a communication between the membrane and a circular opening called the foramen ovale, F. The next division of the ear is called the labyrinth, and consists of the cavity G, of the semi-circular canals H, and of the cochlea I. Over this complex inner compartment, which is filled with water, the nerve of hearing is spread as a lining. The action of the principal parts is as follows: the pulsations of the air are impressed upon the membrane, causing it to vibrate. These vibrations are continued through the agency of the chain of bones to the foramen ovale, when they are received by the nerve, which transmits the sensation to the brain.

Musical Sounds.

There is a peculiar character in sounds, depending on the character of the sounding body. A blow with a hammer, or the report of a pistol, produces only a noise. But if a body be of such a thinness and lightness as to produce a succession of impulses of a sufficient degree of quickness, a *tone* is the result; namely, a sound composed of a great number of noises all so close upon each other, that they bring but one result to the ear. In a *noise*, or unmusical sound, the waves follow each other like those of the sea, with no regularity either in their intervals or intensities. The more regular they are, the more clear or musical is the sound.

The principal sounds in music are only seven in number. The notes are of different degrees of shrillness, one rising above another in succession; they are named, do, re, mi, fa, sol, la, si, or by the first seven letters of the alphabet, as represented at fig. 8.

The difference of sounds which depends on the different number of vibrations in the sounding body in a given time, divides them into bass, low, or grave notes, for comparatively few and slow vibrations; and those called high, shrill, or sharp, for vibrations more numerous and quick.

The frequency of vibrations on strings increases with their shortness, lightness, and tension. Fig. 9, illustrates the vibrations of a string A B, which is made fast at both ends, and being drawn on one side to C, it will not only return to its original position, but proceed onwards to D. This is its first vibration; at its termination, the string will again tend to return to its natural state, A B, and it will therefore return to that line, and pass on beyond it to E, and thence back again to F, then in the same manner to G and H; the resistance of the air continually lessening the motion till the whole is destroyed, and the string comes to rest in its original position. The vibrations, whether large or small, are performed in equal times.

If a common violin string be extended between two points on a board, and screwed up, it may be made,

according to its length and degree of tension, to vibrate when struck exactly 240 times in a second. The note which it thus produces is C or do; and a person, on trial, will find that this is the note with which he is most apt to begin a song when he attempts to sing. The note in his voice will be perfectly in unison with the note produced by the string, that is, they melt into and agree with each other, and the effect will be pleasant. This is because the membrane at the top of the singer's windpipe vibrates exactly the same number of times in a second producing that note, as the spring does. Thus, the same note produced on any musical instrument is due to the same number of vibrations per second, and, however different the quality of these notes, as given by different instruments may be, they all agree in *pitch*, and this is determined by rapidity of vibration. By shortening the string we increase the number of vibrations per second in the same ratio inversely, so that if the string be shortened one half, its vibrations will be doubled, giving a note an octave higher than the preceding one, and in this way all the different notes may be produced.

Musical Instruments.

As the first, the most beautiful, of musical instruments, must be mentioned the human voice; which is formed by the air from the lungs passing through an opening at the back of the mouth, called the glottis. The glottis may be considered as the pipe of an organ, and the lungs as serving the office of the bellows. Such are the admirable properties of the glottis, that from one and the same orifice, which is not quite an inch long, and not more than the twentieth of an inch wide, arise all the various modulations of which the human voice is capable. These it produces by having the power of enlarging or contracting the orifice through which the air from the lungs below is transmitted. The different cavities of the nose and mouth give a sort of echo to the voice, when formed, and contribute to its force and clearness.

Musical instruments are usually divided into three distinct classes, namely: first, stringed or membranous instruments, as the harp, drum, &c.; secondly, wind instruments, as the organ, French horn, flute, &c.; thirdly, metallic instruments, as bells, cymbals, musical boxes, &c.

The action of the hand upon the harp, the bow upon the violin, the fingers upon the tambourine, or the sticks upon the drum, all cause vibration. The sound produced does not in the first instance, arise from the vibrations acting upon the external air, but in the constriction of the atmospheric particles interspersed within the elastic animal fibre, and these particles thence expanding into the surrounding air, originate the production and diffusion of sound. Where the elasticity is destroyed by damp, motion is produced without occasioning sound, as in a wet drum head.

With respect to the sounds produced by wind instruments. The effect is caused by the vibrations of a column of air confined at one end, and either open or shut at the other; the length of the sounding column determining the nature of the vibrations. In the flute, clarionet, bassoon, &c., into which the air is propelled in nearly an equable manner, harmony is occasioned by opening and closing apertures in the side, thus dividing the whole column of air into regular portions. In such instruments as the trumpet, horn, &c. the harmony is propelled by the mouth and lips, the metallic surfaces merely deepening the intonation. In organs, each tube is constructed to utter a separate note, and the harmony is produced by opening or shutting the tubes at pleasure, by the action of keys.

Metallic instruments, as bells, are dependent upon their composition and relative size for their diversity of tone. The notes of musical boxes are regulated by the length and thickness of their springs, which, being elevated by points fixed in a moveable barrel, produce in their rebound, the degree of harmony required. In all these instances it will be observed that the same principle prevails of a constrictile power being first produced, which afterwards leads to that modified expansion which creates sound, tone, and harmony.

OPTICS.

Optics is the science of light and vision.

All visible bodies may be divided into two classes, *self-luminous*, and *non-luminous*. The first comprises those bodies which shine by their own light, as the stars, sun, flames, &c. Non-luminous bodies are those which have no power of discharging light of themselves, but which throw back the light that falls upon them from self-luminous bodies. Light emitted from a self-luminous body is projected in straight lines in every possible direction; so that the luminous body not only seems the general centre whence all the rays proceed, but every point of it may be considered as a centre which radiates light in every direction, (fig. 1). A ray of light is a straight line of light projected from a luminous body, and a pencil of rays is a collection of rays proceeding from any one point of a luminous body, (fig. 2).

When rays of light meet with an opaque body through which they cannot pass, they are stopped short in their course, and cause the opaque body to form a shadow on the other side of it. If the luminous body (as A, fig. 3) be larger than the opaque body, (B) the shadow will gradually diminish in size till it terminates in a point; if smaller, the shadow will increase in size as it is more distant from the object that projects it, (fig. 4). A number of lights in different directions, while they decrease the intensity of the shadows, increase their number, which corresponds with that of the lights, (fig. 5).

Reflection of Light.

When a ray of light falls perpendicularly on an opaque body, it is reflected back in the same line towards the point whence it proceeded; if it falls obliquely, it is reflected obliquely, but in the opposite direction, the

angle of reflection being equal to the angle of incidence, (fig. 6).

The principle of reflection may be illustrated by the case of a plane mirror, or looking glass, (A B, fig. 7). The ray from the eye of the spectator at C will be reflected in the same line, C A; but the ray D B, coming from the foot, in order to be seen at the eye, must be reflected in the line B C, and therefore, the foot will appear behind the glass at E, along the line C B E, because that is the line in which the ray last approached the eye.

There are three kinds of mirrors used in optics; the plane or flat, the convex, and the concave; the reflection of the two latter is very different from that of the former. A convex mirror has the peculiar property of making the reflected rays *diverge*; and a concave mirror makes the rays *converge;* and under certain circumstances, magnifies the image.

M N, fig. 8, represents a convex mirror, formed of a portion of the exterior of a sphere, whose centre is O. A B C, are three parallel rays, the middle one of which only, is perpendicular to the centre of the mirror, and is reflected in the same line; the two others falling obliquely, will be reflected obliquely to G and H, the dotted lines, P P, being perpendiculars which divide their angles of incidence and reflection. By continuing the reflected rays G B, and H E, backwards, they will meet at F, their virtual focus behind the mirror.

If A B, fig. 9, be an object placed before the convex mirror (M N), and lines be drawn from its extreme points A B, to O, the centre of the sphere, a diminished representation of the object will be formed at the focus.

Fig. 10, illustrates the property of a concave mirror. A B C, are three parallel rays, which striking the mirror, are reflected, the middle ray in the same line, and the two others converged so as to meet at the focus F, midway between the surface of the mirror, and the centre of its concavity C. The dotted lines, P P, are perpendiculars.

Images reflected from concave mirrors appear larger than the real objects, provided these objects are within the focus, as A B, fig. 11; and the image of an object receding from a concave mirror, becomes continually greater, provided it does not recede beyond the focus, in which case it will appear less and inverted.

A B, fig. 12, is an object placed at some distance in front of a concave mirror. In this case, a small and inverted image of the object will be formed at D E; and a series of instructive experiments may be made by varying the distance of the object, and observing the variation in the size and place of the image. When the object is placed at D E, a magnified representation of it will be formed at A B.

Concave mirrors are used as burning glasses. Fig. 13, represents a lens so constructed as to refract the sun's rays, and collect them into a focus, where the concentrated heat becomes so intense as to ignite substances, and even to fuse metals.

Refraction of Light.

Refraction is the effect which transparent mediums produce on light in its passage through them. Opaque bodies *reflect* the rays; transparent bodies *transmit* them: but it is found that if a ray, in passing from one medium into another of different density, fall obliquely, it is turned out of its course, or *refracted;* but if it fall perpendicularly it is not refracted, but proceeds through the new medium in its original direction.

Let A C, fig. 14, be a vessel half filled with water. If a ray strike it in the perpendicular direction, A B, it will be continued in the same line to C; but if a ray be admitted at D, it will strike the water obliquely at B, when it will become subject to two opposite forces, the attraction of the water endeavouring to draw it perpendicularly to C, and the projectile force of the ray inducing it to proceed in its original direction to F; the consequence will be, that it will pursue an intermediate course to E.

If a coin be placed in a basin, so that on standing at a certain distance, it be just hid from the eye of an observer by the edge of the basin, and then water be poured in by a second person, the first keeping his position; as the water rises the coin will become visible, and will appear to have moved from the side to the middle of the vessel, (fig. 15).

These facts lead to an important axiom in optics; namely, that we see everything in the direction of that line in which the rays approach us last. Hence, the sun is seen several minutes before it comes to the horizon, and as long after it has sunk beneath it, because its rays strike first upon the atmosphere, and are by it refracted or bent towards the earth, (fig. 16).

In passing through a pane of glass the rays suffer two refractions, but which, being in contrary directions, produce nearly the same effect as if no refraction had taken place. A A, fig. 17, represents a thick pane of glass seen edgeways. When the ray B approaches the glass at C, it is refracted to D; at that point returning into the air, is again refracted, but in a contrary direction, and in consequence proceeds to E. But this is the case only when the two surfaces are parallel to each other; if they are not, the two refractions may be made in the same direction. Thus, when the parallel rays (fig. 18) fall on a piece of glass having a double convex surface, that ray only which falls in the direction of the axis of the lens is perpendicular to the surface; the other rays falling obliquely are refracted towards the axis, and meet at a point beyond the lens called its focus.

Figs. 19 to 23, represent sections of lenses of various forms, having different refractive properties. The property of those which have a convex surface is to collect the rays of light to a focus; and of those having a concave surface to disperse them. The rays falling on the concave lens, fig. 25, will each be attracted towards its thicker extremities, both on entering and quitting it; and will, therefore, by the first refraction be made to diverge to A C, and by the second to *d e*. The ray B, falling perpendicularly on the axis of the lens, suffers no refraction.

Lenses which have one side flat, and the other convex or concave, as figs. 19 and 20, are called plano-convex, and plano-concave. The focus of the former is at the

distance of the diameter of a sphere, of which the convex surface of the lens forms a portion as shown at fig. 26.

Fig. 24, represents a section of a prism, the principal use of which is to enable us to decompose rays of light.

Decomposition of Light.

White light, as emitted from the sun, or other luminous body, is found to be composed of seven different kinds of light; namely, *red, orange, yellow, green, blue, indigo, and violet;* and this compound substance may be decomposed or separated into its elementary parts

Fig. 27, represents a prism, so placed, that a beam of light, admitted by a small aperture, A, falls upon it, and being refracted is thrown upon the screen B C, forming an oblong image called the *prismatic spectrum,* containing the seven colours already named. The lowest portion of it is a brilliant red, shading off by imperceptible gradations into orange, the orange into yellow, the yellow into green, the green into blue, the blue into a pure indigo, the indigo into violet. If the spectrum be divided into 360 parts, the red will occupy forty-five of them, the orange twenty-seven, the yellow forty-eight, the green and the blue sixty each, the indigo forty, and the violet eighty. The union of these colours in this proportion produces in us the idea of whiteness.

The Rainbow.

This brilliant and many coloured arch is occasionally seen spanning the sky opposite the sun. Rainbows are only visible when rain is falling between the spectator and that part of the sky which is opposite to the sun. The bow is formed by the sun's rays falling upon the upper parts of the drops of rain, and being then by refraction, thrown on another part of same drop, where they are again refracted and reflected to the eye, so as to produce the successive colours from the upper part of red, orange, yellow, green, blue, indigo, and violet, (fig. 28). The second bow which is occasionally seen exterior to the first, proceeds from the double refraction; its colours are less vivid, and their order is reversed.

The Eye—Vision.

Figs. 29 and 30, represent a front view and a section of the eye. The eye is composed of three coats or skins, one covering the other. The external coat is called the *sclerotica,* (*a a*) it is deficient in the fore part of the eye, but its place is supplied by the *cornea,* (*b b*) which slightly projects, and is transparent. The second coat is called the *choroid,* and is a membrane lining the inner surface of the sclerotica, and is covered on its inner surface with a black pigment; immediately within this pigment and close to it, lies the *retina,* (*r r*), the innermost coat of all. This is a delicate reticulated membrane, formed by the expansion of the optic nerve, which enters the eye at the back of it. In looking through the cornea from without, we perceive a flat circular membrane called the *iris,* and in its centre a circular opening (*e*) called the *pupil,* which expands or contracts, according to the quantity of light. Within the coverings of the eye-ball are contained three transparent substances, called *humours.* The first of these occupies the space immediately behind the cornea, and is called the *aqueous humour,* (*c*); behind this is situated the *crystalline humour,* (*d*); and the back part of the eye, or the space between the crystalline humour and the retina, is occupied by the *vitreous humour.* These different humours form a compound lens which refracts the rays of light rebounding from objects, forming an image of them upon the retina, the sensation being transmitted by the optic nerve to the brain.

Telescopes.

There are many varieties of telescopes; the one represented at fig. 31, is called a *refracting telescope,* and consists of four double convex lenses. The rays proceeding from an object A B, are first refracted by the lens C, and we obtain an inverted image at G; the rays then pass through D and E, by which transit they bring the image upright at H, and by the lens F, the rays are transmitted to the eye. Telescopes of this kind magnify, or bring near, in proportion as the focal distance of the object glass is greater than the focal distance of the eye-glass.

Fig. 32, represents the *reflecting telescope.* The peculiarity of this instrument is, that the object is reflected from a concave mirror within the tube, and the image is again reflected by a small mirror to the eye. The concave mirror A B, has a hole in its centre at C; its principal focus is at D E, here the image is inverted, and the rays crossing each other at F, go on to the small reflector G. From this they are reflected in parallel lines through the hole C, and entering the plano-convex lens are magnified, and transmitted through another lens to the eye. In order to accommodate focal distances, the small mirror can be moved by means of the rod and screws L M.

Fig. 33, represents the *camera obscura,* This interesting optical instrument consists of a convex lens A, through which the rays of any objects are admitted into a darkened chamber, where they fall on a plane mirror B, placed at an angle of forty-five degrees; by this they are reflected upwards against a plate of ground glass C, upon the upper surface of which the objects appear in their natural colours.

Fig. 34, represents the *magic lantern,* within which, behind the lamp, is a reflector A, which projects the light through the lens B, and thus strongly illuminates the objects painted on glass which are placed before it in the opening C D, the rays passing through them and the lens E, fall on the screen opposite.

The dissolving views are exhibited by means of two lanterns, and while the view in one is being gradually withdrawn, the view in the other is being gradually brought forward.

ELECTRICITY.

Electricity is the operation of a subtile fluid, generally invisible, which appears to be diffused through most bodies.

If a stick of sealing wax, or a watch glass be rubbed upon a dry piece of woollen cloth, it will be found while

warm by the friction, that they have acquired the property of attracting small light bodies, as feathers, &c. Some of these will adhere to the surface of the wax or glass, and others will be thrown off from the body as if they were repelled from it. This phenomena may be strikingly exemplified by the small apparatus represented at fig. 1. A is a stand with a bent wire, to which at the hook B, a fine silk thread is attached, having at its extremity a very small pith ball C. If the glass rod D be rubbed and presented to the ball, this will be immediately attracted to the glass, and will remain in contact with it for a few seconds; if the glass be now withdrawn, and again presented to the ball, the latter will be repelled, (fig. 2). If instead of the glass a piece of sealing wax rubbed in the same way be employed, the same effect is produced. Both these electrics have therefore in the first place, the power of *attracting* another body before they have communicated to it any of their own electricity; and, secondly, having communicated a portion of their electricity, they *repel* it. But a very remarkable circumstance takes place, if we, after having conveyed electricity to the ball C by means of excited glass, should present to it after the former was withdrawn, excited sealing wax, the ball instead of being *repelled*, as it would be were the glass again applied, is *attracted* by the wax. If the experiment be reversed, and the excited wax first presented to the ball, and then the excited glass, the latter will be found to repel the ball. Hence, we conclude that there are two opposite electricities; namely, that produced by excited glass, to which the name of *vitreous* or *positive* electricity has been given; and that produced by excited wax, to which the name of *resinous* or *negative* electricity has been given.

Fig. 3, represents the *Cylindrical Electrical Machine*, consisting of a hollow cylinder of polished glass C C, revolving upon an axis supported by two upright pillars of glass fixed in a wooden stand. Two hollow metallic conductors D E, are placed parallel to the cylinder on either side, upon two insulating pillars of glass. To one of these conductors (E) a cushion is attached and held close to the cylinder by means of a screw; from the upper edge of the cushion there proceeds a flap of oiled silk, which extends over the upper surface of the cylinder to within an inch of a row of metallic points, proceeding like the teeth of a rake, from a horizontal rod fixed to the side of the opposite conductor. When the cylinder is driven round by the handle, the friction of the cushion upon it produces a transfer of the electric fluid from the latter to the former; that is, the cushion becomes negatively and the glass positively electrified. By the revolution of the cylinder, the fluid adhering to the glass is carried round, and its escape prevented by the silk flap until it arrives near to the metallic points which absorb most of the electricity, and convey it to the prime conductor D, which thus becomes positively electrified, while the other conductor, having parted with this electricity is negatively electrified.

Fig. 4, represents the *Plate Electrical Machine.* The plate is turned by the handle through the rubber, which is coated with a metallic amalgam, and diffuses the excitement over the glass, the points carrying off a constant stream of positive electricity to the prime conductor, upon the principle already described.

Fig. 5, represents the *Hydro-Electric Machine*, an apparatus of recent date and construction, and of immense power. It consists of a steam boiler, A, insulated on stout glass pillars. The steam is made to issue through a great number of bent iron tubes B B, terminating in jets of wood. An insulated projecting conductor C, is placed in connection with the boiler, for the purpose of collecting the excited electricity; and another conductor D, formed of a metallic case having several rows of points, is placed immediately in front of the jets, to receive and carry off the opposite electricity of the steam, and prevent its return to the boiler, by which the excited forces would be neutralized. The electricity thus produced is the result of the friction of condensed particles of water, whilst being driven by the still issuing steam through the jets, these watery particles performing the office of the glass plate, or cylinder of the common machine, and giving out vitreous electricity. The wood jets and pipes act as the rubber, and give out resinous electricity.

Electricity can, like heat, be transferred or communicated from one body to another. An electrified ball can be deprived of its electricity by being touched with a metallic rod, but if we touch it with glass or wax, the electricity will remain unaffected. Hence, metals are said to be *conductors*, and glass and wax *non-conductors.* Bodies differ greatly in their power of conduction. A list of the principal substances that possess these properties will be found on the Diagram. The most connenient mode of obtaining an accumulation of electricity, is by employing a cylindrical glass jar, coated within and without nearly to the top with tin-foil, and having a cover of baked wood incased with sealing wax to exclude moisture and dirt. A metallic rod rising above the jar and terminating in a brass knob, is made to descend through the cover and communicate with the interior coating. An apparatus of this kind is called a *leyden jar*, and is represented at fig. 6. The jar is charged by presenting the knob to the prime conductor of a machine in action, and upon its removal, if a communication be made by a wire extending from the external coating to the knob, the electric fluid which was accumulated in the positive coating, rushes with a sudden and violent impetus along the conductor, and passes into the negative coating with a loud snap and flash of light, thus at once restoring the equilibrium.

Fig. 7, represents a discharging rod, for establishing a communication between the inner and outer coating of the jar. The handle is of glass to prevent the operator from receiving the charge of the jar.

By uniting a sufficient number of jars, we are able to accumulate a large amount of electricity. Such a combination of jars is called an *electrical battery*, (fig. 8).

If it is desired to send the charge of electricity through any particular substance which may be the subject of experiment, the connecting conductors must be so arranged, as that the substance shall form a necessary part of the *circuit of the electricity*, as it is termed. With this

view it must be placed between two good conductors, one of which is in communication with the outer coating, and the circuit may then be completed by connecting the other conductor with the inner coating by means of a discharging rod. The electric fluid will always pass through the best conductors, although they may be more circuitous, in preference to those which are more direct, but have inferior conducting power; and when different paths are open for its transmission along conductors of equal power, the electricity will always take that which is the shortest.

Fig. 9, represents an instrument called the *Universal Discharger*, which is used for passing charges through any substance that may be laid on the plate A. The end of one wire is connected with the positive conductor, and the end of the other with the negative conductor of a machine.

Fig. 10, represents an *Electro-meter*, an instrument used to detect the presence of electricity. If charged either by placing the instrument on one of the conductors of a machine, or on the rod of an electrical jar, the reed rises and marks as an index on the graduated semi-circle the angle of divergence, by which the comparative amount of electrification may be estimated. The hairs upon the well known electrical toy, represented at fig. 11, are spread out and stand on end, upon the same principle.

Fig. 12, represents two bells suspended from a brass wire D D, supported by a glass pillar A. The electricity being conducted to the knob E, passes down the wires D D to the bells, which are then *positively* electrified, and attract the clappers C C, that are *negatively* so, in consequence of being insulated by silken strings. The clappers having become charged, strike against the centre bell to discharge themselves, and thus a peal is rung on the bells till the electricity is taken off.

Electric sparks are of a bluish colour in the atmosphere in its ordinary state, and their character depends almost entirely on the form, area, and electrical intensity of the discharging surfaces. If the small ball P (fig. 13), be attached to the prime conductor of a machine, and a larger ball N be presented to it, a series of brilliant sparks of a crooked or zigzag form, will pass from the smaller to the larger ball. When, however, electricity is given off from sharp points, it is unaccompanied by noise, and presents the brush like appearance represented at fig. 14.

The influence of pointed conductors on electrically charged bodies, was first observed by Franklin, who showed that when presented to them, their charges became silently and rapidly dissipated. Hence the utility of pointed conductors to secure buildings from the effects of lightning, (fig. 15).

Voltaic Electricity or Galvanism.

The production of electricity in this case arises from the corroding action of an acid upon metallic surfaces. The acid being interposed between two plates of dissimilar metals, usually copper and zinc, and the zinc being the more oxidable, gives out positive electricity. The two plates are connected together at the top by a wire, and this communication establishes what is called a voltaic or galvanic circuit; the electricity circulating round the zinc, wire, copper, and liquid, (fig. 16).

There are many forms of galvanic batteries. Fig. 17, represents Daniell's battery, consisting of a cylinder of copper containing a porous tube, having a solid rod of amalgamated zinc in its centre. Fig. 18, represents Griffin's improved Smee's battery, consisting of six cells; the plates are arranged upon a frame suspended, by means of a rod and racket wheel, over the trough containing the exciting liquid. By this arrangement, any desired degree of power may be obtained by merely raising or depressing the frame.

MAGNETISM.

The theory of magnetism bears a very strong resemblance to that of electricity. Like it, magnetism has its attractions and repulsions, and it can be excited in one body and transferred to another; with however, this striking peculiarity, that carbonized iron or steel, is nearly the only substance capable of exhibiting any strong indication of its presence. The *loadstone*, or natural magnet, (fig. 1), is a hard, dark coloured mineral, found chiefly in iron mines; it is, however, seldom used, as its properties can be imparted to bars of steel, which may be made more powerful than itself.

Fig. 2, illustrates the polarity of the magnet. If a bar or needle, which has been rendered magnetic, be accurately poised on a point, one of its ends will point towards the north, and the other towards the south; hence, those parts of the magnet are termed the *north* and *south poles*.

The reciprocal attractions, repulsions, and neutralizations of the opposite magnetic forces may be illustrated by straining a piece of paper upon an open frame and placing it over a bar magnet, (N S, fig. 3). If some iron filings be now sifted upon the paper screen, the particles will arrange themselves in a series of curved lines, proceeding from similar points on each side of the middle of the bar, others will stand out at the extremities, as if repelled from the poles N S. If the *opposite* poles of two magnets be presented to each other, at about two inches distance, and iron dust be projected over them as before, similar results will ensue. Magnetic lines proceeding from similar points of each bar, will appear uniting the two poles, as represented at fig. 4. If two *similar* poles be presented to each other, the lines of force, mutually repelling each other will present the appearance shown at fig. 5.

Fig. 6, represents the horse-shoe form of magnet, in which the two poles are brought near together, so as to attract a piece of iron by their combined force.

The earth itself, is found to be a vast magnet, having its two magnetic poles situated in the neighbourhood of,

but at some distance from its poles of revolution. This is the reason why magnetised needles point in a north and south direction, not to the earths's axis, (except at certain places), but to the magnetic poles. This will be seen by reference to fig. 7, which represents compass needles distributed over the globe, all lying in the direction of lines drawn from one magnetic pole to the other.

Fig. 8, represents the mariner's compass, the most essential part of which is a magnetised bar of steel, called the needle, accurately poised on a fine central point within a bowl or case, which is so supported as always to preserve a horizontal position. Upon the needle is placed the circular card represented at fig. 9, the ornamental point N being placed over the north pole of the needle, consequently, the points round the circle indicate the cardinal, and all intermediate points.

The inclination, or *dip* of the needle—that is, its deviation from the horizontal plane, affords a manifestation of the influence exercised upon it by the magnetism of the earth. Hence, a dipping needle, poised on a horizontal axis, (as fig. 10) will, when carried to either of the earth's magnetic poles, stand *upright*, the end which is upward at one pole, being downward at the other. The further we recede from either pole, the less does the needle dip, as shown at fig. 11, where the dotted lines indicate the lines of equal dip, or parallels of *magnetic latitude*, and A and B, the north and south *magnetic* poles.

Electro Magnetism.

This department of science is founded on the connection ascertained to exist between electricity and magnetism. A, fig. 12, represents a bar of soft iron, bent into the horse-shoe form, around it is coiled a quantity of copper wire covered with silk. The ends of the wire are connected with the poles of an active voltaic battery, the electricity from which passing along the coiled wire, converts the soft iron bar into a powerful *electro-magnet*, capable of sustaining by its attractive force a weight of many hundred pounds, and which it will continue to support so long as the connection with the battery is maintained, but the moment that connection is broken, the magnetic power of the iron ceases, and the weights fall.

The magnetic action circulates round the wire in two currents, moving in opposite directions, as represented at fig. 13. The wire being electric along its length and magnetic across.

Fig. 14, illustrates the action of electric currents upon a magnetic needle. A A is a coil of copper wire, B a magnetic needle freely poised, and pointing north and south. If the wire C be connected with the copper pole, and the wire D with the zinc pole of an active voltaic battery, the needle will turn eastward; and upon reversing the wires, the needle will turn westward. Upon this simple principle depends the action of that astonishing apparatus the Electric Telegraph, of which our limits will only allow a very brief description.

Fig. 15, represents a front view of the Telegraph instrument in which two needles are employed. Upon the dial plate are arranged the letters and figures, with marks indicating the number of times and the direction, in which the needle is to be moved for each letter. At the top of the instrument within an ornamental case is placed a bell or alarum to call attention to the instrument when a communication is about to be made. The alarum is put in action by a current of electricity being passed through a coil of wire encircling a piece of soft iron, which is thus converted into an electro-magnet, and attracts a lever, by which clock-work is set in motion, and the hammer caused to strike the alarum.

Fig. 16, represents the internal mechanism for moving each needle. The handle shown on the front of the instrument is attached to and works the cylinder A, to this a projecting pin is affixed at B, and another at C. When the handle is turned to the right, the pin B is brought into contact with a spring D, bending it backwards so as to separate it from the point on the brass rod E, and bringing the pin C into contact with the base of the spring F. The current of electricity from one pole of a battery then passes from the pin B down the spring along a strip of brass to the terminal G, thence along the wire, as indicated by the arrows, and passing through the instruments at the different stations, deflects their needles to the right, and being conducted at the extremity of the line to a large piece of metal buried in the ground, is thence conducted by the earth to the terminal H, up the strip of brass, through the coil I, deflecting the needle within it to the right, and terminating at the base of the spring F, with which the other pole of the battery is connected. When the handle of the cylinder is turned to the left, the current of electricity is reversed, and consequently, the needles move to the left also.

Magneto-Electricity.

As magnetism is derived from electricity, so electricity may be obtained from magnetism. If a piece of soft iron, A A, fig. 17, encircled by coils of copper wire be brought into, or removed from contact with the poles of a magnet B B, electrical currents of considerable magnitude are produced in the wire, and sparks will pass between the ends of the wire P and N. To produce the effect, it is essential that the magnet be in motion, or that the conductor be in motion across the magnet.

CHEMISTRY.

The material world immediately within our observation is found to consist of fifty-five simple or elementary substances, which, having hitherto resisted all endeavours to divide them into any others, are termed *elements of matter*. They are arranged into two grand divisions, under the names of non-metallic and metallic elements, (see diagram).

Non-Metallic Elements.

Oxygen. This is a permanently elastic gas, colourless, destitue of taste and smell, and is the chief support of life and heat. It is one of the most important agents in

nature, there being scarcely a single process, whether natural or artificial, in which oxygen has not some important share. It forms eight-ninths of water, one-fifth of air, and about one half of all earthy matters. Its basis gives the acid character to all mineral and vegetable salts; and the calcination of metals is altogether effected by their union with oxygen.

Oxygen may be procured by placing in a glass retort (A, fig. 1) some chlorate of potash, and on applying the heat of a spirit lamp, the gas will be given off, and being conducted by the tube B, will rise in the glass jar C, inverted in the pneumatic trough D.

Nitrogen or *Azote*, is a substance generally diffused throughout nature, and particularly in animal bodies. This gas is elastic, transparent, colourless, and inodourous; it destroys animal life, and a burning taper immersed in it is instantly extinguished. Four parts of nitrogen and one of oxygen, constitute atmospheric air. Nitrogen acts in the atmosphere as a damper, preventing combustion, and respiration from going on too fast.

Hydrogen. This gas is transparent and colourless, and when pure is destitute of taste and smell. It is the lightest body with which we are acquainted, being nearly fourteen and a half times lighter than the air. It forms one of the constituent parts of water, which is composed of eighty-five parts by weight of oxygen, and fifteen of hydrogen. Hydrogen will not support combustion, but is itself remarkably combustible.

Chlorine. This gas is of a greenish colour, of a strong suffocating smell, and astringent taste. If breathed undiluted it destroys life, but it supports combustion. Its most essential property, however, is its power of destroying vegetable colours, hence, its great importance in bleaching.

Iodine and *Bromine.* These substances much resemble chlorine in their properties; they destroy vegetable colors, but not so completely as chlorine. They are highly poisonous.

Fluorine. This substance is obtained from fluor, or Derbyshire spar, Combined with sulphuric acid, it forms an intensely active fluid, named hydro-fluoric acid.

Carbon. This is another simple substance extensively diffused throughout nature. It is found pure and solid only in the diamond; but may be obtained in the state of charcoal, by burning wood in a close vessel, or covered with sand. Carbon enters into the composition of bitumen and coal, and of most animal and some mineral substances. It forms nearly the whole of the solid basis of all vegetables, from the most delicate flower to the stately oak. It combines with iron in various proportions, and the results are cast iron and steel; it also combines with all the supporters of combustion; and with oxygen forms carbonic acid. *Carburetted Hydrogen* is a compound of carbon and hydrogen, which, mixed with oxygen, or sufficient air, forms an explosive mixture, which takes fire on the application of naked flame. In coal mines, this gas was very destructive to human life, until Sir H. Davy discovered that if the flame of the miner was surrounded by wire gauze, that no explosion took place, hence his invention of the safety lamp, (fig. 2).

Sulphur. This is a simple substance, the appearance of which is well known. It is an abundant ingredient in various minerals, as in iron and copper pyrites. It is inflammable, burning slowly with a pale blue flame, emitting strong suffocating fumes, which, when collected, form sulphuric acid. It is the base of several compound substances, and is of great use in the arts.

Silenium, is a substance nearly allied to sulphur in its nature; it melts at 212°, and on cooling becomes solid, having a metallic lustre; it is soft and easily reduced to powder. *Boron,* is an opaque brownish powder, which is infusible. At about 600° it takes fire, and combines with oxygen, forming boraic acid. *Silicon* is a brownish coloured powder, and is very similar to boron in its appearance and relations to other matter. It can be exposed to a very high temperature without being fused.

Phosphorus. This is another simple combustible substance, but which is never found in a pure state in nature. It is commonly united to oxygen in the state of phosphoric acid, which is found in different animal, vegetable, and mineral substances. When pure it resembles beeswax, and is so very combustible that it takes fire in the air, and appears luminous in the dark.

Metallic Elements.

Before the discoveries of Sir Humphrey Davy, not only were the alkalies, as potash and soda, imagined to be simple bodies, but also the substances known by the names of earths. But this great philosopher proved that potash, soda, and lithia, were metallic oxides; and subsequently, it was ascertained that baryta was the oxide of a metal called *barium*, and strontia the oxide of a metal called *strontium*, lime the oxide of *calcium*, and magnesia of *magnesium*. The five non-alkaline earths have been also found to possess a similar constitution, and are oxides of the metals to which their names refer, (see Diagram).

Metals, such as iron, copper, lead, &c., are familiarly known to every one, but there are a great many others which are very rarely to be met with. A list of the whole will be found upon the Diagram.

The following are some of the characters which distinguish metals from other bodies. They all possess metallic lustre, they are mostly hard, heavy, and are all opaque; they are insoluble in water, admit of high polish, of being melted by heat, and of recovering their solidity by cooling. They are of different *colours;* some are white, as platinum, palladium, nickel, silver, tin, and mercury; some are bluish-white, as lead, zinc, iron, manganese, uranium, antimony; two are yellow, namely, gold and titanium; copper is red; bismuth reddish, cobalt has a pale reddish tint. Some of them possess the property of *malleability.* Gold and silver may be beaten out into leaves almost inconceivably thin. Copper, tin, platinum, and lead, possess the same property, but less perfectly; others are totally destitute of it, as arsenic, antimony, columbium, and cobalt, and they can easily be reduced to powder. Hence, such bodies are termed *brittle* metals. Metals differ much in their *cohesion* or *hardness.* Tungsten is so hard as to resist the file; on the other hand, lead and tin may be scratched with one's finger nail. In regard to the *fusibility* of metals, they

differ from each other as much as in any other respect. Some are absolutely infusible in the greatest heats of our furnaces, as platinum, iridium, rhodium, and molybdenum. It requires the most powerful heat to melt manganese, nickel and iron. Others melt long before they become red hot, as tin, lead, and bismuth; while potassium at common temperatures, is always an easily moulded, soft solid; and mercury remains in a liquid state.

Metals combine with oxygen, but they differ very much in the facility with which they unite with it. Some, by mere exposure to the air, absorb its oxygen with great rapidity, as potassium and sodium; others more slowly, as iron, manganese, and arsenic; and lead and copper still more slowly. Others do not oxidate by exposure to the air, unless at a high temperature, as tin, zinc, mercury, antimony, and bismuth. Others again will not oxidate by exposure to the air or heat, or by immersion in water, as gold, platinum, palladium, iridium; and silver is with great difficulty oxidized by heat. By combining the metals with oxygen, they can be invested with new properties, which may be employed in the promotion of the fine arts. The metallic substances generally occur in the earth in what are called *veins*, and are seldom found in the pure metallic state, but generally in combination with other substances, in which case they are called *ores*.

From the variety of metals which abound on our globe, we derive manifold advantages; their uses are so multiplied, that they are become of the greatest importance in almost every department and occupation of life.

Caloric, or Heat.

This element appears to pervade the whole system of nature. It is called *sensible* caloric, when it produces the sensation of heat; and *latent* caloric, when it forms an insensible part of the substance of bodies. All bodies, with very few exceptions, are capable of expansion by heat; the gases to the greatest extent, liquids less so, and solids least. The expansion of fluids may be illustrated by the *thermometer*, (fig. 3); the mercury in the bulb of which expands by the application of heat, and rises in the tube in proportion to the heat applied. Fig. 4, represents the *air thermometer*, consisting of a tube with a bulb containing air. The bulb beneath contains a coloured liquid, and if a portion of air in the bulb be expelled by heat, it will on cooling, reascend the tube, and indicate changes in the temperature by the rise or fall of the coloured liquid.

The *double air*, or *differential thermometer*, (fig. 5) is a modification of the preceding. To one of the limbs of the tube is affixed a scale divided into degrees. If one of its balls be more heated than the other, the unequal expansion of the included air puts the coloured fluid in motion, and indicates the increase of temperature. This thermometer is chiefly used for delicate experiments upon the radiation of heat, indicating the degree of heat accumulated in a particular point, while the surrounding atmosphere is but little affected.

Fig. 6, represents the *pyrometer*, an apparatus for measuring the expansion of solid bodies. The metal rod A being heated by the flames, expands in length, and pressing against the wheel B, turns it, and the index marks the degree of expansion.

When fluids are subjected to a greater pressure than that of the atmosphere, they require a greater quantity of heat to make them boil. This fact is illustrated by the apparatus, fig. 7. Into the hollow globe A is first poured some quicksilver, into which the end of the tube B is immersed. The globe is then half filled with water, and the stop cock being closed, and heat applied, the temperature soon rises above the boiling point, as indicated by the thermometer C inserted into the boiler. When the heat arrives at 218 degrees, the mercury will be elevated to six inches in the tube by the elastic pressure of the steam, and gradually rising, at 242 degrees, the elasticity of the steam will balance a column of mercury thirty inches high, being equal to the pressure of one atmosphere.

All bodies do not radiate heat alike, for their surfaces have great power of promoting or retarding the motion of caloric. If a cubical canister A (fig. 8) four inches square, of polished tin, be filled with boiling water, and placed at three feet distance from a concave tin reflector B, which has the non-graduated ray of a differential thermometer C in the focus, the quantity of radiated caloric will be denoted by the rising of the fluid in the graduated ray to 120 degrees. But if the canister be brushed over with a mixture of size and lamp-black, the thermometer will rise to 200 degrees. If a frame D having gold leaf over its centre be placed between the canister and the reflector, the whole of the heat will be intercepted by this thin metallic substance, and no effect will be produced upon the thermometer.

Fig. 9, represents the *blow-pipe*, by which the flame of a candle is made to produce an intense heat. This useful instrument is employed in the operations of fusing, soldering, &c.

Fig. 10, represents the *alcohol blow-pipe*. The alcohol in the globe, being boiled and converted into vapour by the heat of the flame beneath, and the vapour being made to issue out at the jet against the flame, causes a stream of most intense heat to play upon any substance submitted to its action.

Fig. 11, represents a *still*. Distillation is that process by which the volatile particles of a body or fluid are vapourized, condensed, and collected in appropriate vessels. The substance is exposed to such a heat as causes it to assume the gaseous form, in which state it is conducted by a worm tube through a vessel of cold water, by which it is condensed into a liquid state, and runs out at the extremity of the tube.

Fig. 12, represents *Papin's digester*, which is constructed on the principle of mechanical pressure being necessary to elevate fluids to a higher temperature than those of common boiling points.

PROPERTIES OF BODIES.

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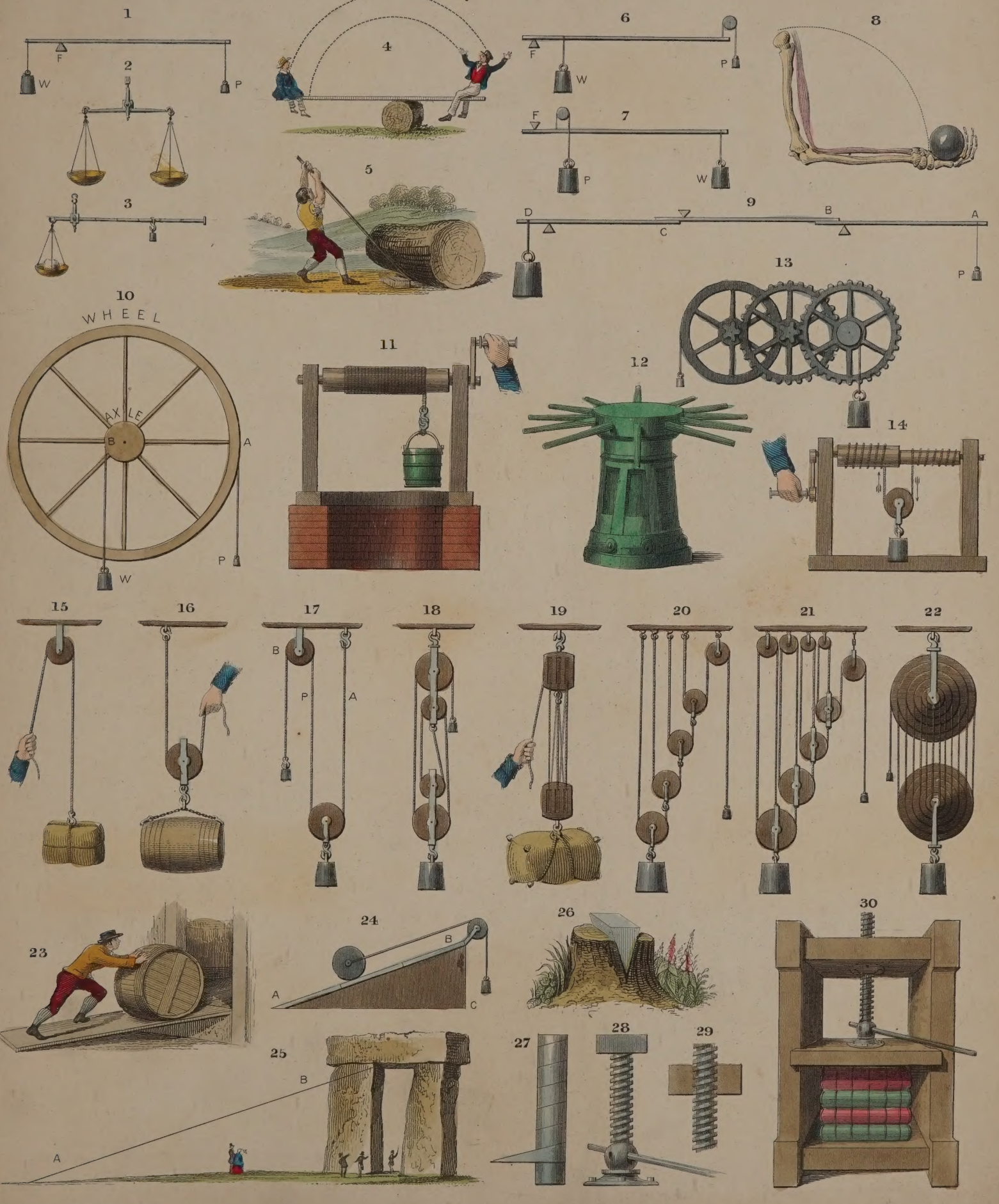

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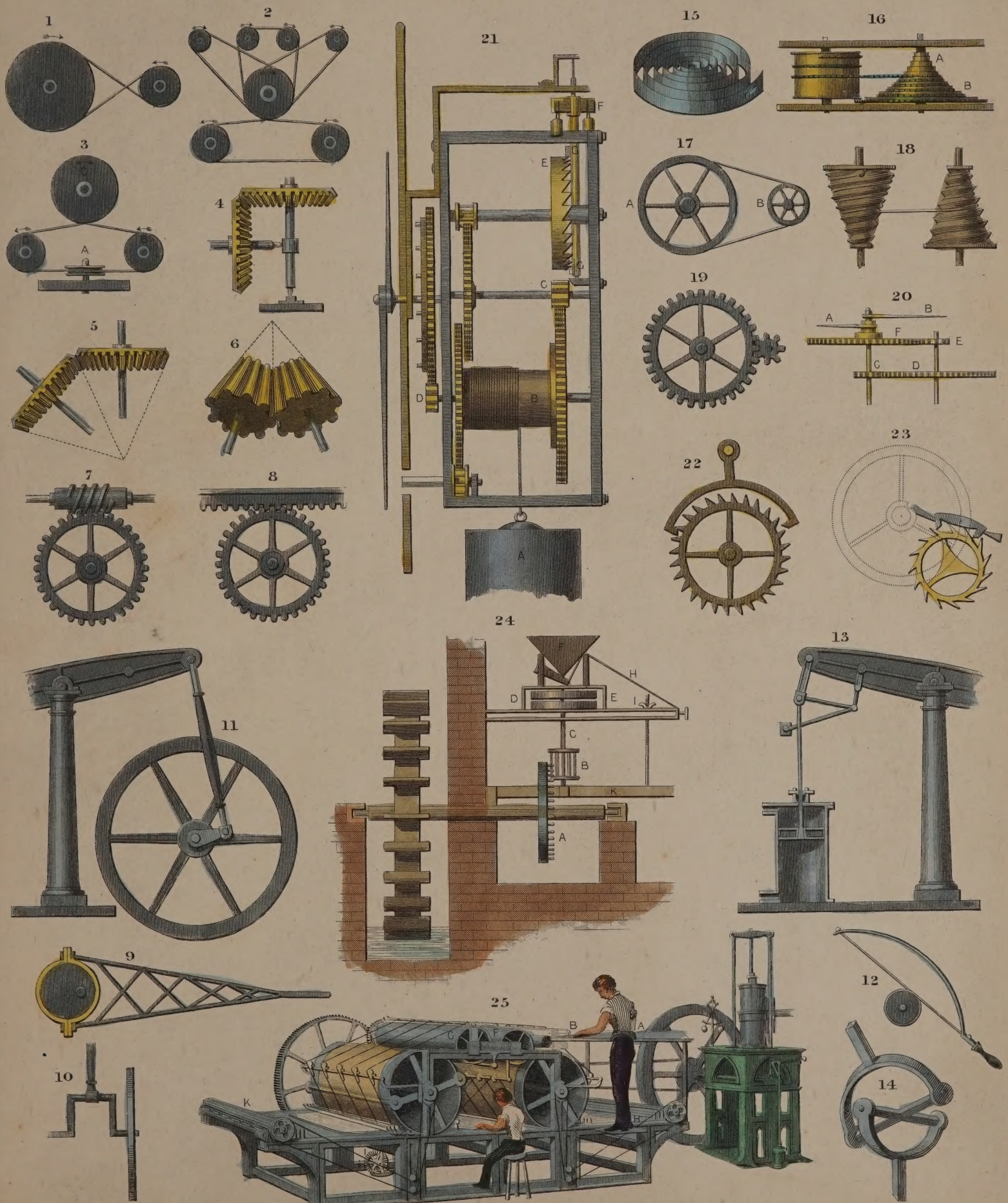

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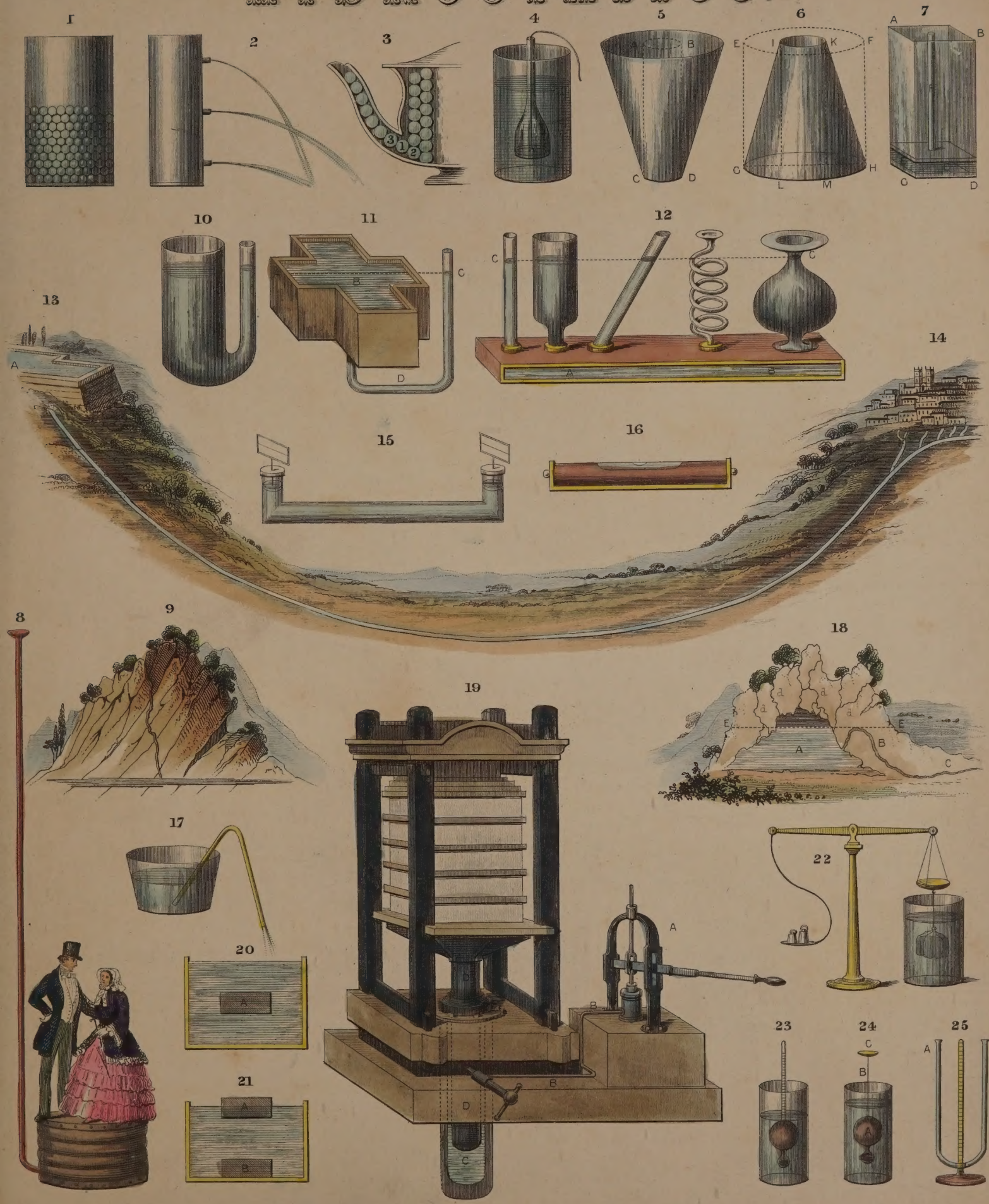

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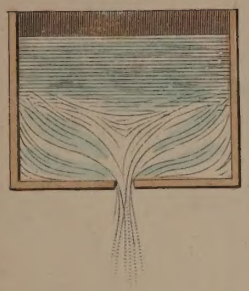

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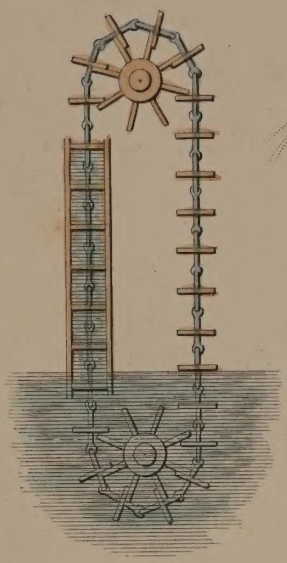

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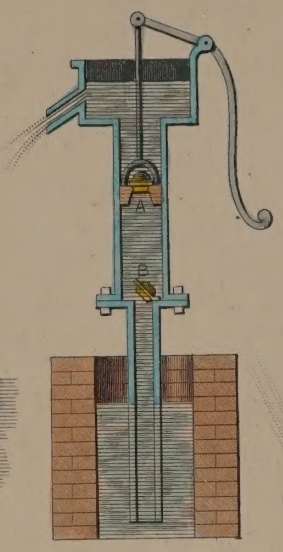

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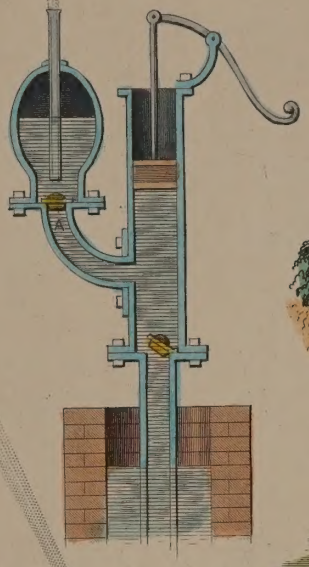

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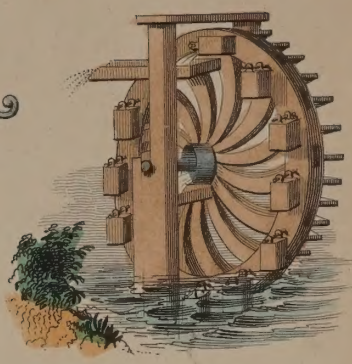

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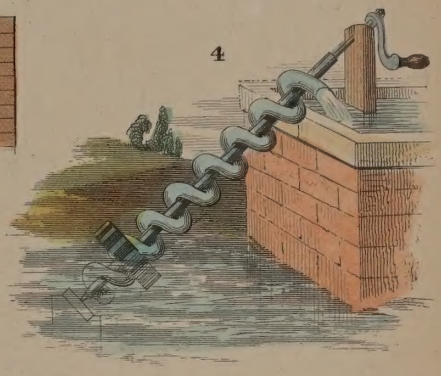

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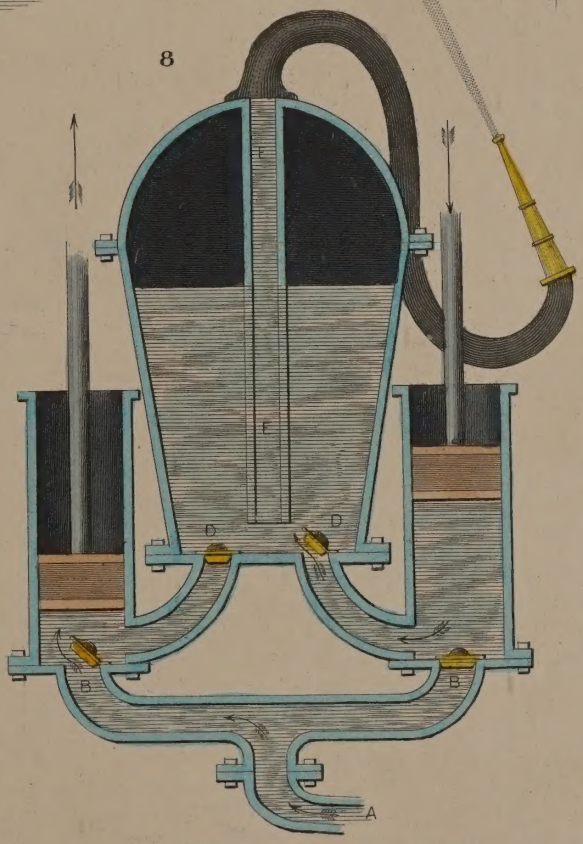

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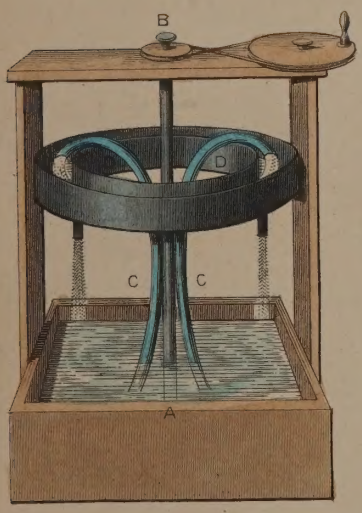

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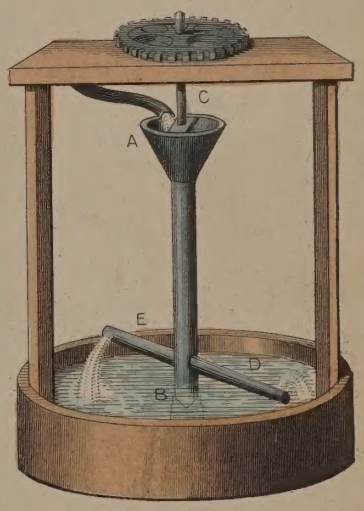

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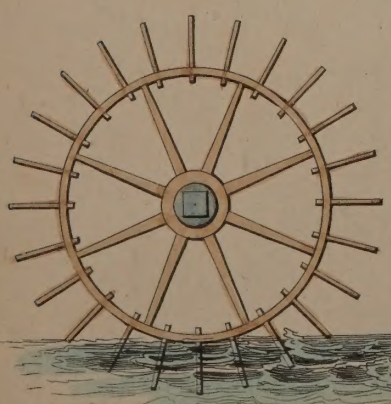

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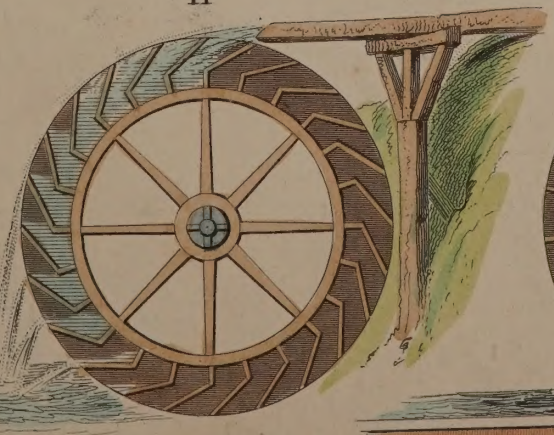

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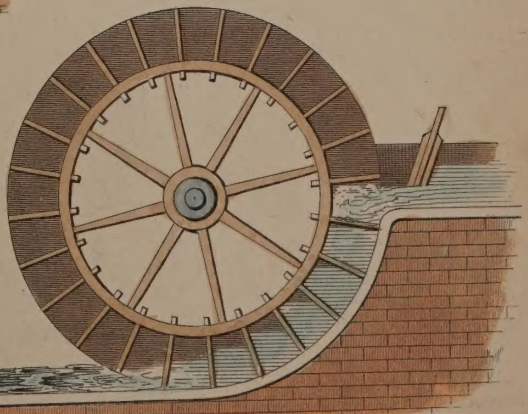

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PNEUMATICS.

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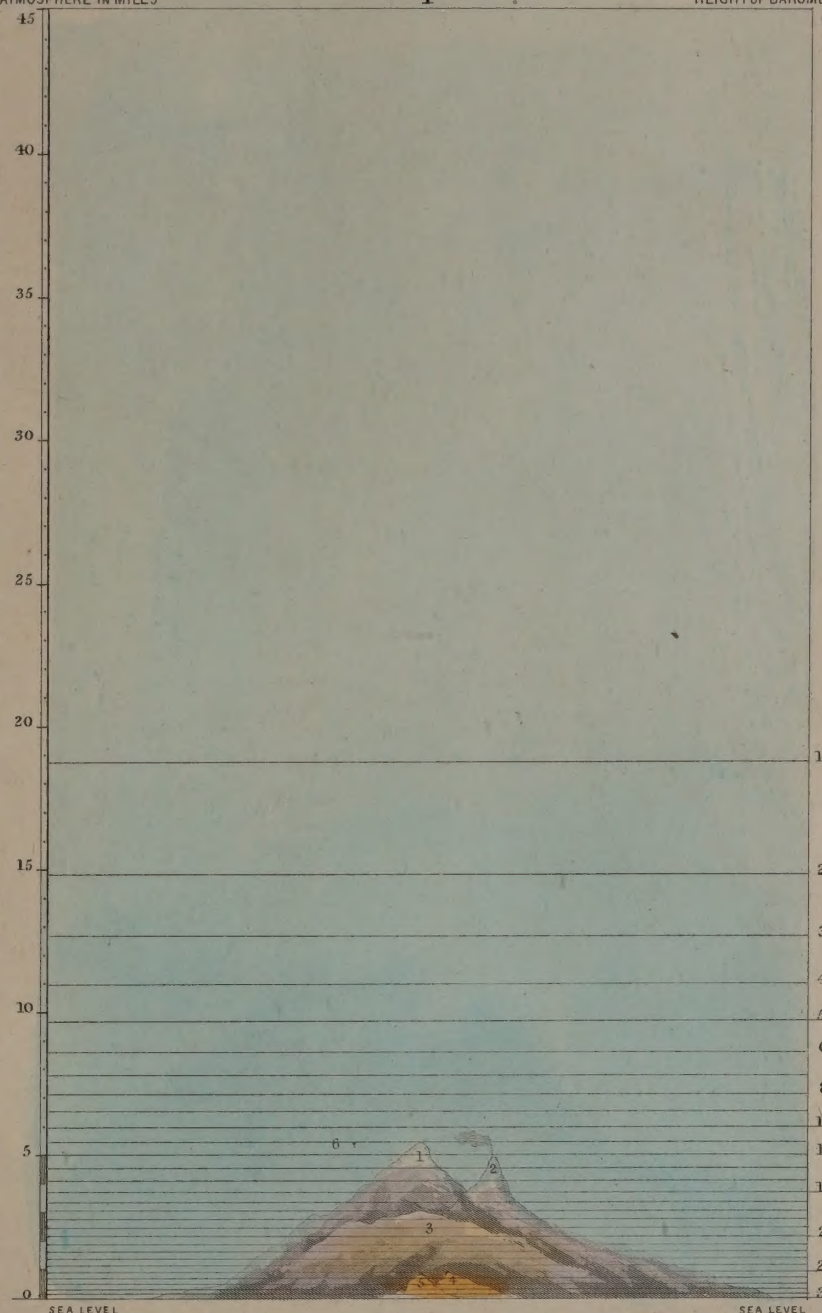

1 Himalaya 28000 feet. 2 Andes 25,250 feet. 3 Alps 15 650 feet. 4 Ben Nevis 4,350 feet.
5 Snowdon 3,571 feet. 6 Mr Green's Balloon in 1837, 27,000 feet.

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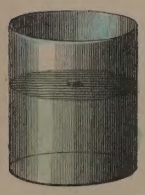

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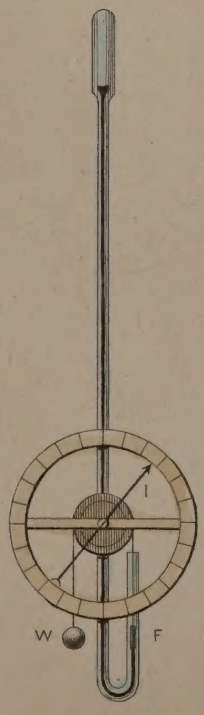

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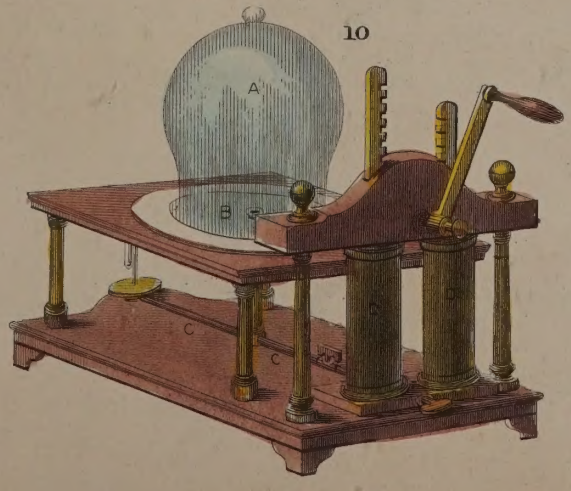

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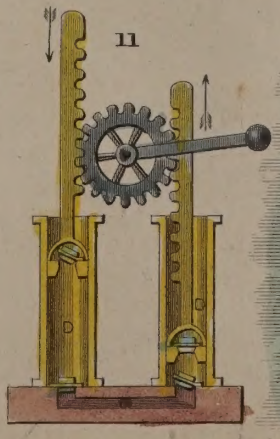

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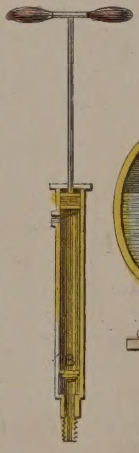

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ACOUSTICS.

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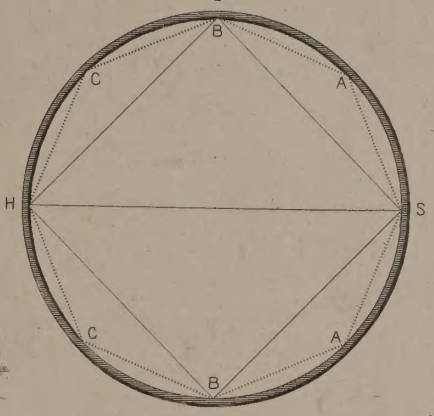

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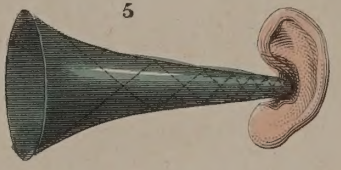

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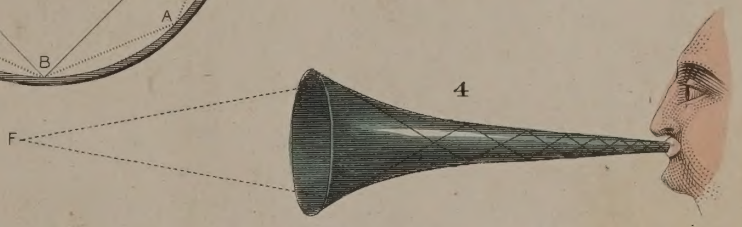

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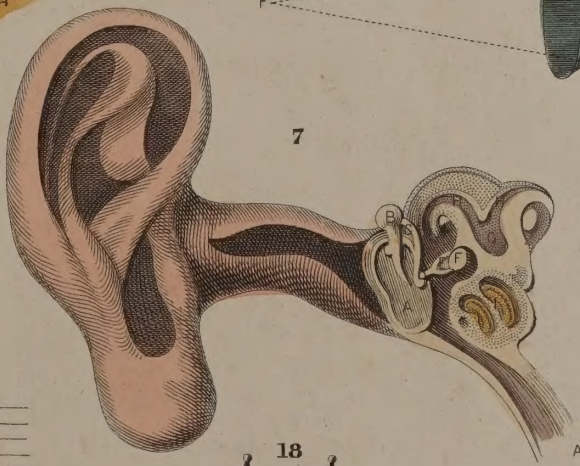

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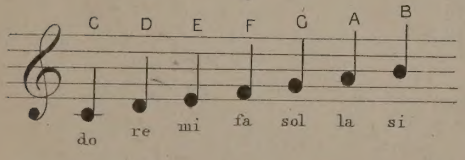
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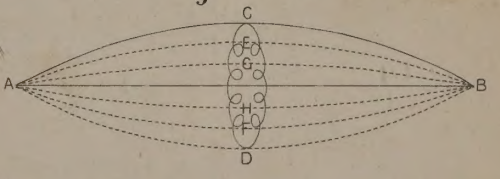

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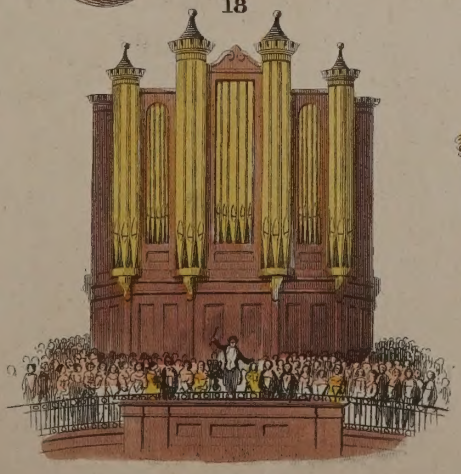

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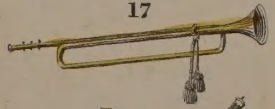

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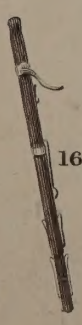

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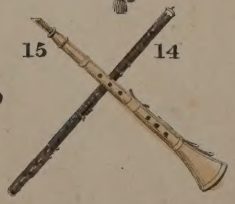

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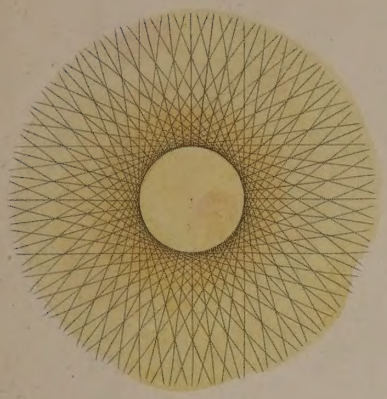

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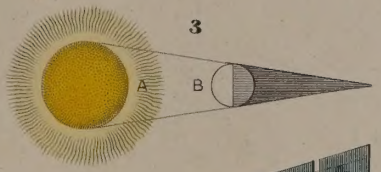

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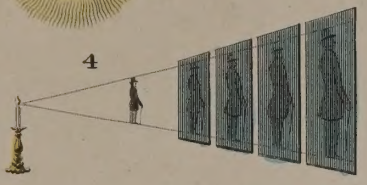

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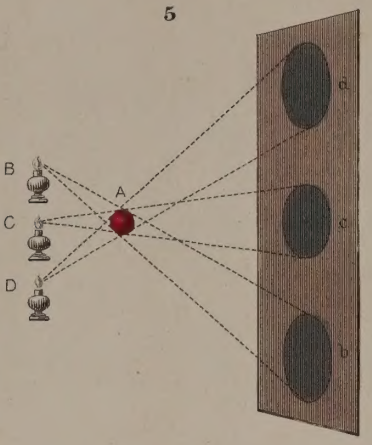

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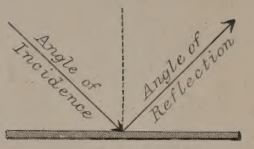

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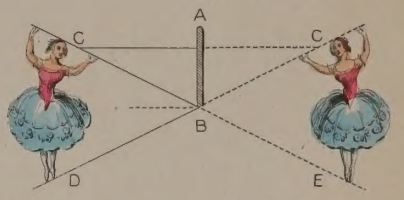

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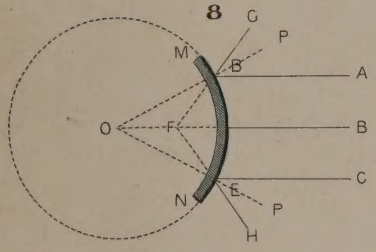

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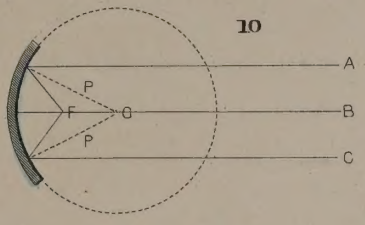

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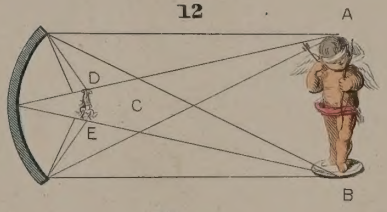

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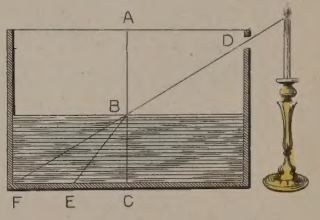

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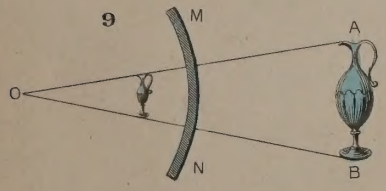

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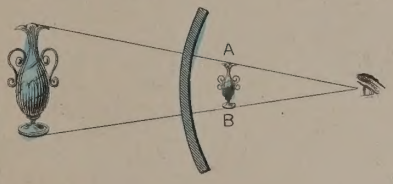

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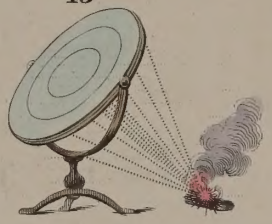

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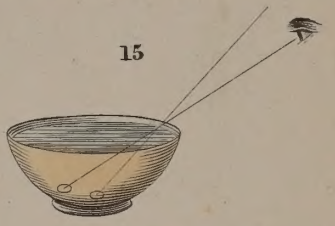

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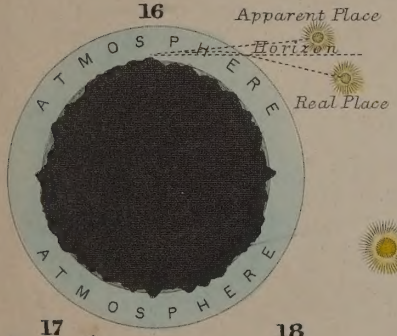

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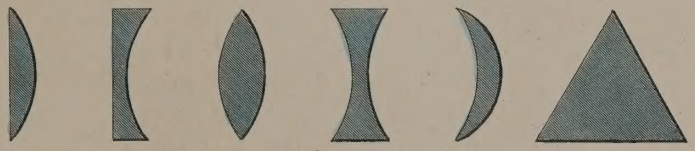

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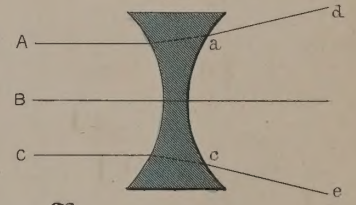

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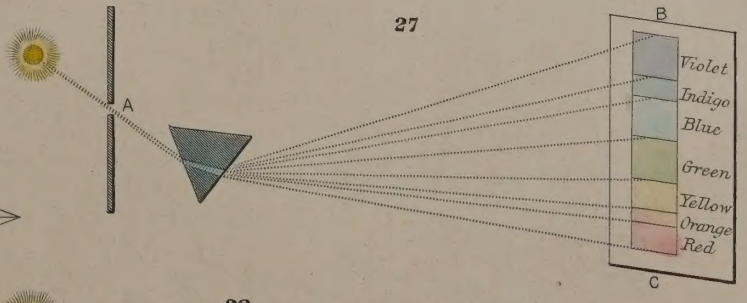

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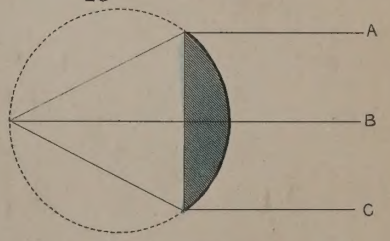

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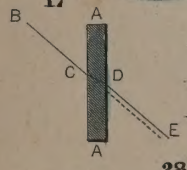

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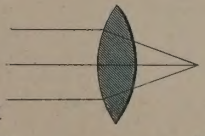

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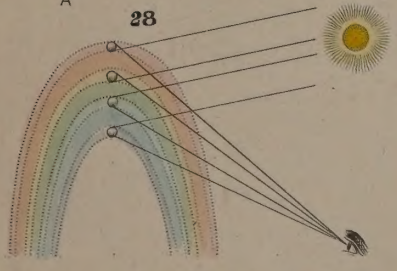

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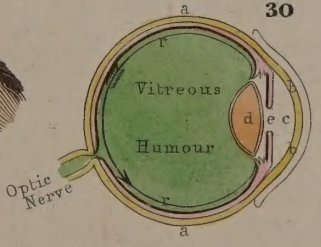

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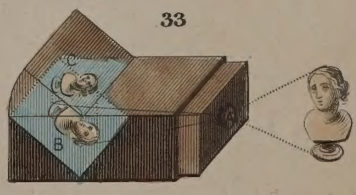

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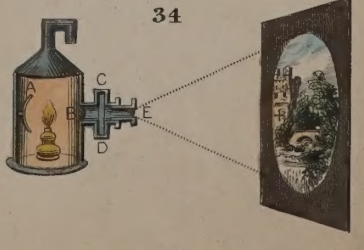

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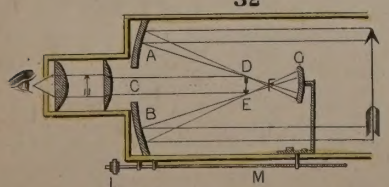

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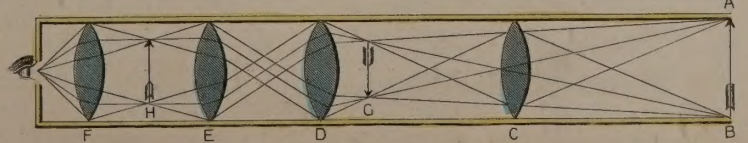

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ELECTRICITY.

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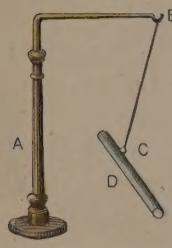

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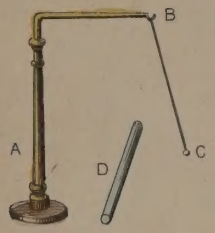

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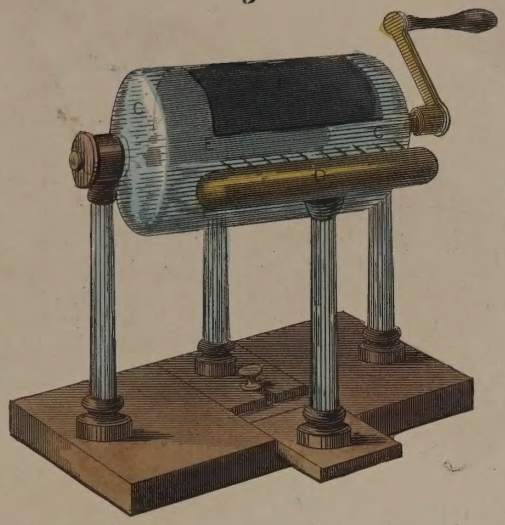

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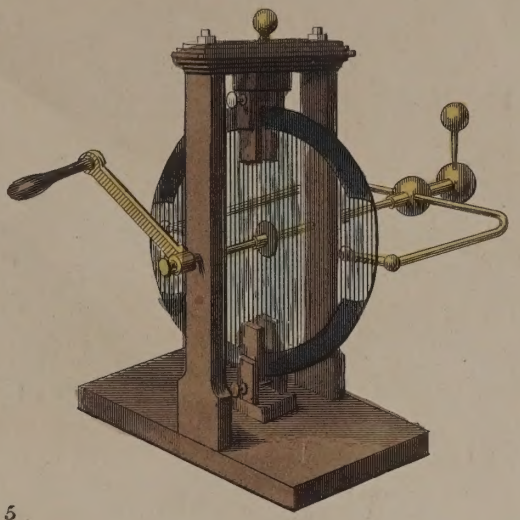

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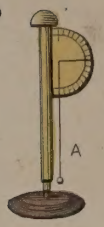

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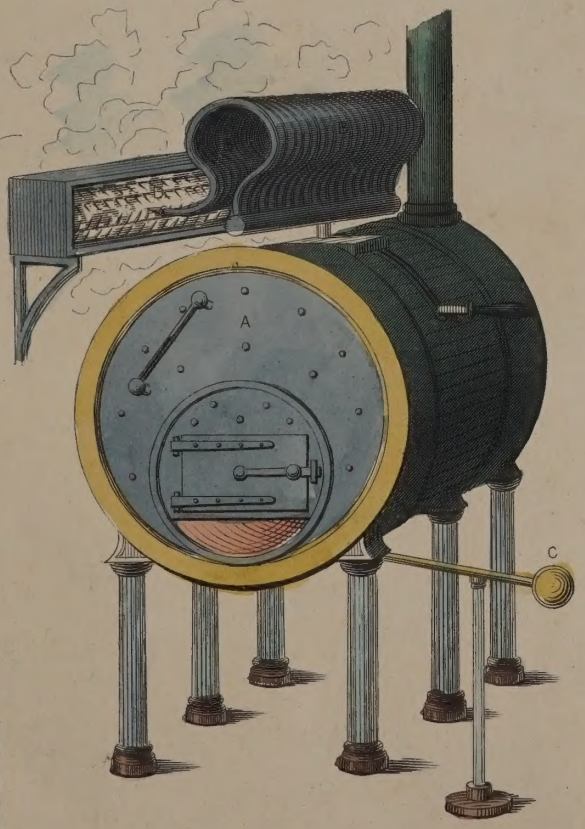

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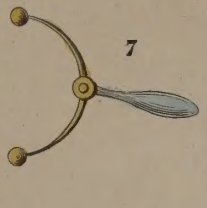

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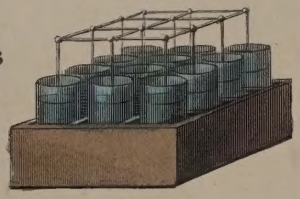


CONDUCTORS

Arranged in order of their Conductibility

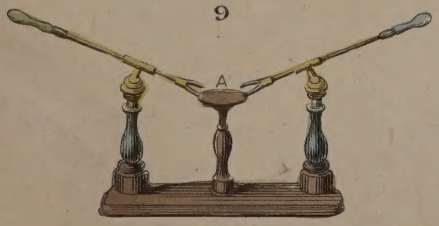
Silver, Copper, Lead, Gold, Brass, Zinc, Tin, Platina, Palladium, Iron, & Metals in General, Charcoal, Plumbago, Concentrated Acids, Diluted Acids, Saline Solutions, Metallic Ores, Animal Fluids, Water, Living Animals & Vegetables Flame, Soluble Salts, Alcohol, Moist Earths.

NON-CONDUCTORS

Arranged in order of their non-conductibility

Shell-lac, Amber, Resins, Sulphur, Wax, Glass, Various Minerals, Silk, Wool, Hair, Feathers, Leather, Air, & all Dry Gases, Baked Wood, Dry Vegetable Bodies, Porcelain, Camphor, Caoutchouc, Dry Chalk, Lime, Phosphorus, Ashes of Animal and Vegetable Bodies, Oils.

9



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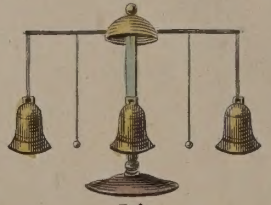

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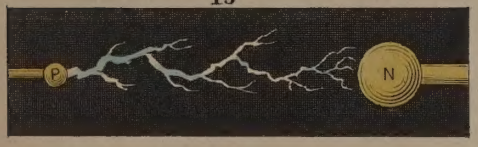

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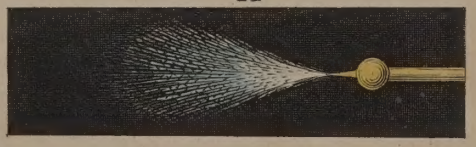

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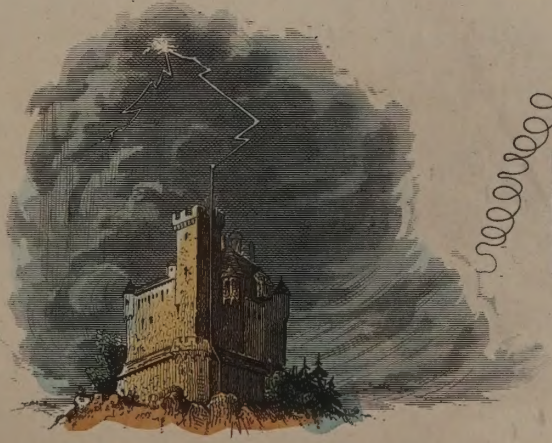

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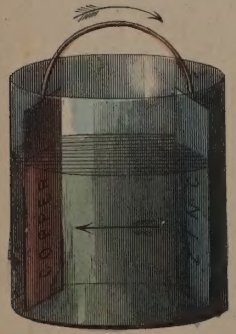

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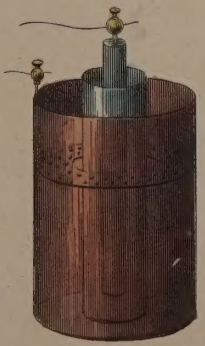

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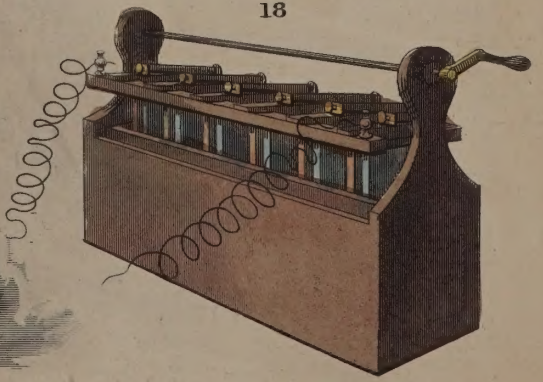

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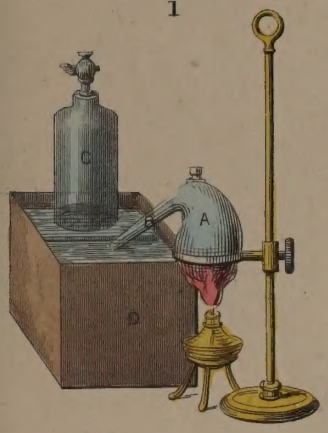
CHEMISTRY.



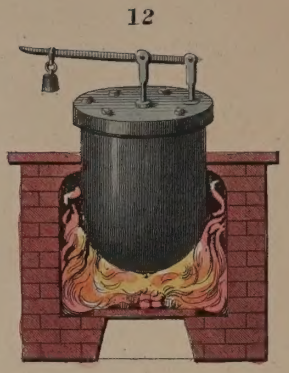


TABLE OF THE ELEMENTS OF MATTER.

NON METALLIC ELEMENTS.

GAZOLITES.

(bodies permanently gaseous.)

Oxygen, Nytrogen, Hydrogen.

HALOGENS.

(bodies which produce Salts when in union with the metals.)

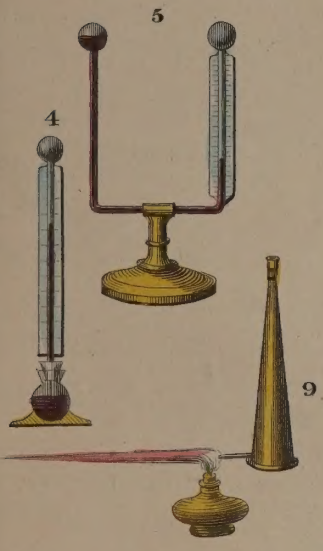
Chlorine, Iodine, Bromine, Fluorine.

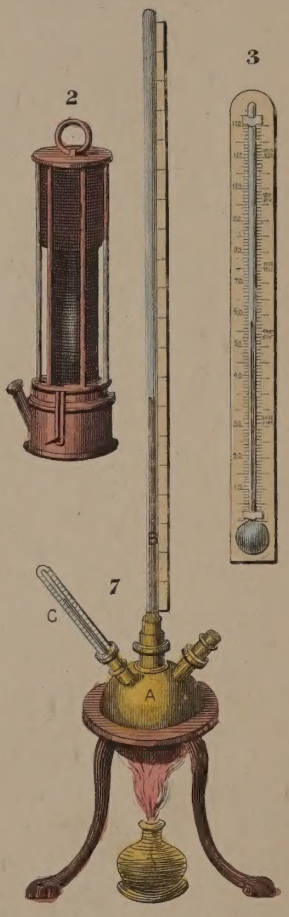
METALLOIDS.

(bodies resembling metals in their chemical relations.)

Carbon, Boron, Silicon, Sulphur, Selenium, Phosphorus.

Oxygen, Chlorine, Bromine, Iodine and Fluorine having a tendency to combine with almost all other substances, and their union being generally accompanied by light and heat, have hence been termed Supporters of Combustion.





METALLIC ELEMENTS.

I

BASES OF THE EARTHS.

Alluminum, Thorium, Glucinium, Zirconium, Ittrium.

BASES OF THE ALKALINE EARTHS.

Calcium, Barium, Strontium, Magnesium.

BASES OF THE ALKALIES.

Potassium, Sodium, Lithium.

II

METALS WHICH DECOMPOSE WATER AT A RED HEAT.

Manganese, Zinc, Iron, Tin, Cadmium, Cobalt, Nickel.

METALS WHICH DO NOT DECOMPOSE WATER BY HEAT ALONE.

Arsenic, Antimony, Tellurium, Chromium, Vanadium, Uranium, Molybdenium, Tungsten, Columbrium, Titanium, Cerium, Bismuth, Lead. Didymium, Lantanium, Copper.

METALS WHOSE OXIDES ARE REDUCED BY A RED HEAT.

Gold, Silver, Mercury, Palladium, Rhodium, Platinum, Osmium, Iridium.

The above 55 Substances comprise the whole of the elements of matter, at present known.

Chemists have arranged the several forms of matter into the four following classes.

SOLIDS.

Which form the principal parts of the Globe, and differ from each other in hardness colour, density, &c.

FLUIDS.

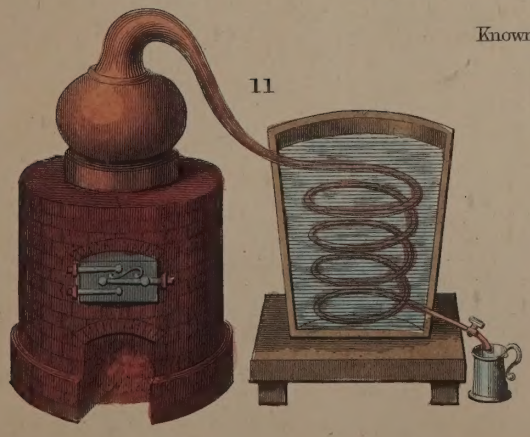
As Water, Oil, &c. whose parts possess freedom of motion, and are generally non-elastic.

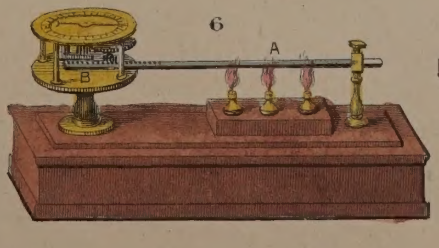
GASES.

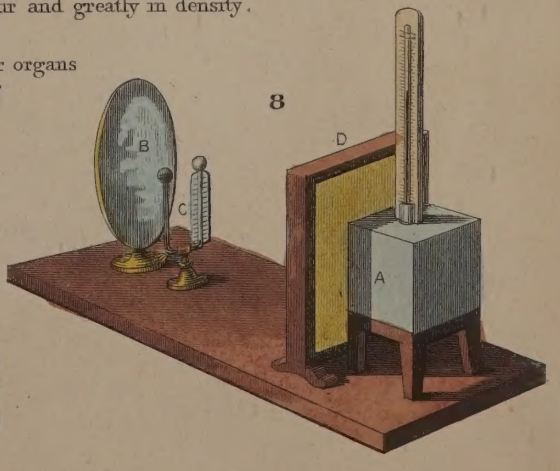
Whose parts are highly moveable, elastic, transparent, varying in colour and greatly in density.

ETHEREAL SUBSTANCES

Known to us only by their motion, when acting upon our organs of sense, and which are not susceptible of being confined. Such are the rays of light, and radient heat.







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